INSTRUCTION MANUAL

BMP5 Transparent Commands

Revision: 9/08

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Section 1. Introduction

This document outlines the structure for a fundamental subset of protocols and packet types used to communicate directly with a single PAKBUS® datalogger. The protocols and packet types discussed in this document are collectively referred to as BMP5 and are used to communicate with Campbell Scientific's native PakBus dataloggers (CR200 Series, CR1000, CR3000, etc.). This documentation assumes the communication link to the datalogger has already been established. Therefore, packets are created, sent, and received over a transparent link directly to and from a single datalogger.

While this document only discusses essential packet types that facilitate communication with a single datalogger, the creation of these packets requires an understanding of packet-switched protocols. With this understanding and through the use of this reference, a developer should be able to send basic packets to and receive packets from a Campbell Scientific CR200 or CR1000 type datalogger.

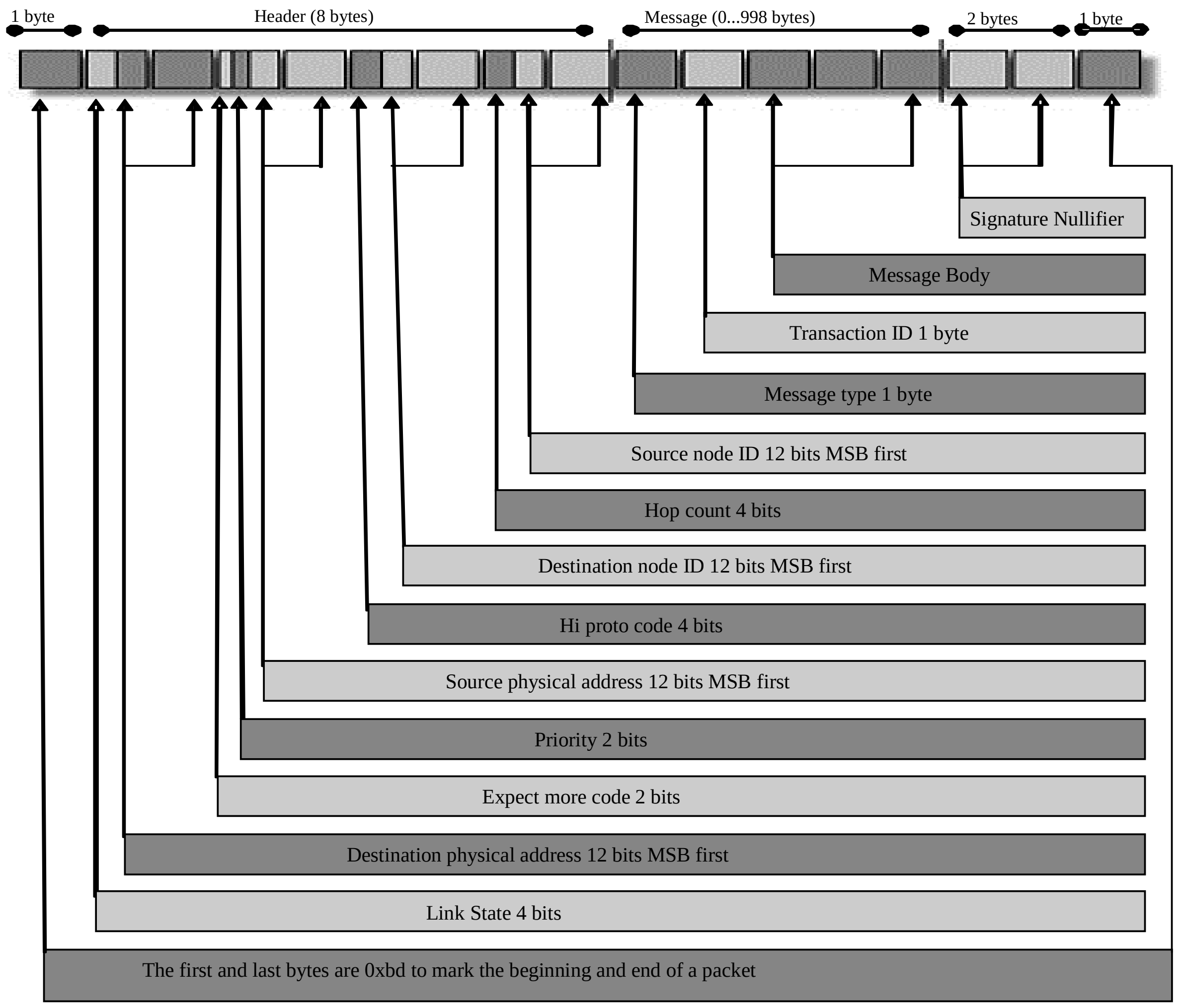
1.1 Communication Layers

Like other types of packet switched communication protocols such as TCP/IP, transparent BMP5 communication relies on a low-level network protocol and higher application level protocols. These different protocol layers exist to facilitate communication between applications and nodes across a given medium. The benefit of using protocol layers is that each layer becomes responsible for a specific function that assists communication. Since these functions are presented in manageable blocks, end-to-end communication is easier because each layer focuses on a single responsibility.

The way a single layer handles a specific task internally can change as long as communication to the protocol layer above and the protocol layer below continues to function in the same manner. For example, the command to check a datalogger clock may exist in the application layer while a separate layer handles the connection. As long as these separate layers communicate with each other, the information can be organized and sent across the network as a complete packet.

The protocol types discussed in this document are the SerPkt Protocol used to monitor the state of the communication link, the PakBus Control Protocol (PakCtrl) used to facilitate PakBus network-level services, and the BMP5 Protocol used to send application messages. An understanding of these message types and the packet structure for these protocols will be necessary to send basic packets to and receive basic packets from a native PakBus datalogger.

1.2 Packet Structure


1 byte
Header (8 bytes)
Message (0...998 bytes)
2 bytes
1 byte
Signature Nullifier
Message Body
Transaction ID 1 byte
Message type 1 byte
Source node ID 12 bits MSB first
Hop count 4 bits
Destination node ID 12 bits MSB first
Hi proto code 4 bits
Source physical address 12 bits MSB first
Priority 2 bits
Expect more code 2 bits
Destination physical address 12 bits MSB first
Link State 4 bits
The first and last bytes are 0xbd to mark the beginning and end of a packet

1.2.1 PakBus Packet Framing and Quote Bytes

PakBus data packets always end with a reserved or special byte code called a SerSyncByte (0xbd[1]) used to identify and isolate each complete packet. Also, one or more SerSyncBytes are transmitted before a data packet. Sending extra SerSyncBytes through an RS-232 interface will clear residual characters from the receiving node's input buffer or wake the node up in preparation for communication.

[1] The character string (0xbd) designates that the characters "bd" are actually hexadecimal representations of the values within the transmission. The character sequence "0x" is a common hexadecimal prefix notation and is used throughout this document when referring to hexadecimal values. Please note that when viewing included log files, the characters "bd" will appear without the "0x" prefix. For reference, the hexadecimal value "b" correlates to the decimal value "11" or the binary value of "1011" while the hexadecimal value "d" correlates to the decimal value "13" or the binary value of "1101".

To ensure that a SerSyncByte doesn't appear inadvertently within the message data, it must be recognized and quoted within the body of the packet before the packet is transmitted. The quoting process is accomplished by replacing reserved bytes with a special code called the QuoteByte. Both SerSyncBytes and QuoteBytes must be found in the packet body and replaced with the following sequence:

SerSyncByte (0xbd) becomes (0xbc 0xdd)
Quote Byte (0xbc) becomes (0xbc 0xdc)

Remember that when receiving a packet, the quoted two-byte codes must be recognized and replaced within the message body by its corresponding value in order to interpret the data correctly.

1.3 PakBus Packet Headers

Along with a SerSyncByte, each packet must contain a PakBus header with the appropriate information to complete the transaction. The header will contain the following:

PakBus Header Information:

Name	**Type**	**Description**
LinkState	bits 7..4	The state of the link described binaurally: 1000: off-line 1001: ring 1010: ready 1011: finished 1100: pause
DstPhyAddr	12 bits	Address where this packet is going (MSB first)
ExpMoreCode	bits 7..6	Describes whether the client should expect another packet from this transaction. 0x00: This is the last message to this destination from this source 0x01: Expect more messages to this destination from the same source 0x02: Neutral message that has no impact on whether to expect more 0x03: Expect more messages in the reverse direction
Priority	bits 5..4	The message priority on the network. Ranges from the lowest priority, 00, to the highest priority, 03. Priority 01 will be sufficient for normal communication.
SrcPhyAddr	12 bits	Address of the node that sent the packet (MSB first)
HiProtoCode	bits 7..4	Designates the type of higher level protocol that will be contained in this packet: 0x00: PakCtrl Message 0x01: BMP5 Message
DstNodeId	12 bits	Node ID of the message destination (MSB first)
HopCnt	bits 7..4	Always zero when connected directly
SrcNodeId	12 bits	Node Id of the message source (MSB first)

1.4 Encoding and Decoding Packets

Reserved characters must be acknowledged and quoted by the application before sending a packet and also recognized and decoded before the application processes a packet. These reserved characters are the SerSyncByte, 0xbd, and the QuoteByte, 0xbc. When these special characters are found within the message body or signature nullifier, they must be handled appropriately.

1.4.1 Quoting the Message Body and Signature Nullifier

Use a QuoteByte, 0xbc, to mark places in the message body or signature nullifier where the SerSyncByte, 0xbd, or the QuoteByte, 0xbc, appear before transmitting the packet. The value of the byte following the QuoteByte is the sum of the quoted character and 0x20. All packets sent by the application must encode the message body and signature nullifier in this manner. An example of packet encoding can be found in the JAVA code in Appendix D.

1.4.2 Unquoting the Message Body and Signature Nullifier

When a packet is received, the application must parse through the message and signature nullifier to find and replace any reserved characters that have been quoted before processing the message. An example of decoding a packet can be found in the JAVA code in Appendix D.

1.4.3 Signature Nullifier

In addition to the PakBus header and packet framing implementation, packets are checked for errors through the use of a two-byte signature nullifier at the end of the data frame. The signature nullifier is a two-byte code that when calculated with the rest of the data frame results in a signature value of zero. Of course, the packet must be unquoted prior to the signature calculation process.

Checking the packet integrity with a signature nullifier enables the application to calculate a running signature as bytes are received and then simply check to see if the signature is zero when the trailing SerSyncByte is received. If the signature is zero, the framed data must be correct and can be confidently processed. Otherwise, the data has become corrupt and must be discarded.

Please note that the signature nullifier field must always be checked to ensure that reserved characters are quoted before transmitting the message and decoded before processing a received message. Additional descriptions of the signature and signature nullifier algorithms and example C code can be found in Appendix B. An additional example of the signature and signature nullifier algorithm can be found in the JAVA code in Appendix D.

1.4.4 Packet Processing Checklist

Data packets received by an application must be examined and processed. The necessary steps to accomplish this process first require that all reserved characters be unquoted in the message body and signature nullifier. After all special characters are unquoted in the packet and signature nullifier but before processing the packet information, the application should make the following checks:

1. Check the length of the packet. If the entire packet length is less than 4 bytes or greater than 1010 bytes, it should be considered invalid and discarded.

2. The DstPhyAddr and DstNodeId fields within the packet header should both equal the address of the application or the broadcast address.

3. The SrcPhyAddr and SrcNodeId in the header should be equal to the address of the datalogger with which the application is communicating.

4. The signature of the entire packet, excluding the SerSyncBytes, should be zero. A non-zero signature indicates a corrupt data packet.

Section 2. Protocols and Packet Types

Packet types from three distinct protocols are described in this document. The SerPkt Protcol used to monitor the state of the communication link, the PakBus Control Protocol (PakCtrl) used to facilitate PakBus network-level services, and the BMP5 Protocol used to send application messages.

2.1 SerPkt Link-State Sub Protocol

SerPkt protocol allows the application and the datalogger to track and control the state of their communication link on the network. The application can request the datalogger's state before attempting to send messages with a "ring" packet. If the datalogger responds with a "ready" packet, the application should be able to proceed with communication.

Some possible link-states sent by the application and a possible response from the datalogger, depending on the state of the device, include but are not limited to the following few examples:

Ring –> Ready
Ready with a message –> Ready with data
Finished with a message –> Ready with data
Finished –> Off-line
Pause –> Finished with or without data

The SerPkt protocol discussed in this section is the Link-state Sub Protocol. If the developer can communicate between the application and the datalogger with this protocol layer, all other protocols discussed in this document should be implemented easily as additional layers working with this SerPkt protocol.

With Link-state Sub Protocol communication, a node initiates a link check and the receiving node responds with a corresponding Link-state Sub Protocol packet declaring the current state. Packets with four bytes of data will only contain the state of the communications link while packets with more than four bytes of data will contain additional link information and possibly even message data. The format for this packet is outlined in the following table.

Link-State Sub-protocol Packet Format:

Name	Type	Description
LinkState	bits7..4	The packet type and the link state: 1000: Off-line 1001: Ring 1010: Ready 1011: Finished 1100: Pause
DstPhyAddr	12 bits	Address where this packet is going
ExpMoreCode	bits 7..6	Expect more communication with this same destination-source pair soon described binaurally: 00: Last 01: Expect more 10: Neutral 11: Reverse
Priority	bits 5..4	Priority – Ranges from 0 as the lowest priority to 3 as the highest priority
SrcPhyAddr	12 bits	Address of the node sending this packet
{ HiProtoCode	bits 7..4	Designates the higher level protocol
DstPBAddr	12 bits	Address where this packet is going
HopCnt	bits 7..4	Hop count – measured from the source node
SrcPBAddr	12 bits	Address of the node sending this packet
{ MsgData }}	Byte [ ]	Message data

2.2 PakBus Control Packets (PakCtrl)

The PakBus Control Protocol (PakCtrl) facilitates communication and network management on the PakBus network by exchanging information between network nodes. Along with the standard PakBus header and SerSyncByte framing characters, all PakCtrl protocol message bodies also include a two-byte header consisting of a message type code used to uniquely identify the format of the rest of the message and a transaction number used to detect orphaned transactions. While the message type code must be specific to the message that follows, the application assigns and monitors the transaction number for each packet.

The PakCtrl message types that an application must be aware of and understand include the following:

2.2.1 Delivery Failure Message (MsgType 0x81)

The delivery failure or fault message is generated at any node on the network when a message cannot be delivered. To avoid an endless loop, fault messages are not generated when an existing fault message cannot be delivered.

Delivery Failure Message Format (MsgType 0x81):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x81)
TranNbr	Byte	Transaction number (always zero)
ErrCode	Byte	Failure code: 0x01: Unreachable 0x02: Unreachable higher level protocol 0x03: Queue overflow (timed out or out of resources) 0x04: Unimplemented command or MsgType 0x05: Malformed message 0x06: Link failed
HiProtoCode	bits 7..4	High level protocol code from the original message
DstPBAddr	12 bits	Destination node address from the original message
HopCnt	bits 7..4	Hop count from the original message
SrcPBAddr	12 bits	Source node address from the original message
MsgData	Byte [0..16]	Up to 16 bytes of MsgData from the original message

2.2.2 Hello Transaction (MsgType 0x09 & 0x89)

The Hello transaction is used to verify that two-way communication can occur with a specific node. An application does not have to send a Hello command to the datalogger but the datalogger may send a Hello command to which the application should respond.

It is important that the application copy the exact transaction number from the received Hello command meassage into the Hello response sent to the datalogger. Since the application is connected directly to the datalogger, the hop metric received in the command message packet from the datalogger can be copied by the application and inserted in the response message packet. In addition, the application should not identify itself as a router in the IsRouter parameter of the response message packet.

Hello Command Message Format (MsgType 0x09):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x09)
TranNbr	Byte	Transaction number
IsRouter	Byte	Indicates whether the source node is a router: 0x00: False 0x01: True

Name	Type	Description
HopMetric	Byte	A code used to indicate the worst case interval for the speed of the link required to complete a transaction (default value of 0x02): 0x00: 200 msec or less 0x01: 1 sec or less 0x02: 5 sec or less (default for RS232 or TCP/IP) 0x03: 10 sec or less 0x04: 20 sec or less 0x05: 1 min or less 0x06: 5 min or less 0x07: 30 min or less
VerifyIntv	Uint2	Link verification interval in seconds

Hello Response Message Format (MsgType 0x89):

Name	Type	Description
MsgType	Byte	Message type code (0x89)
TranNbr	Byte	Transaction number
IsRouter	Byte	Indicates whether the source node is a router. The application should specify 0x00 (False) indicating it is not a router in the response message. 0x00: False 0x01: True
HopMetric	Byte	A code used to indicate the worst case interval for the speed of the link required to complete a transaction (default value of 0x02). The application should copy the value from the command message : 0x00: 200 msec or less 0x01: 1 sec or less 0x02: 5 sec or less (default for RS232 or TCP/IP) 0x03: 10 sec or less 0x04: 20 sec or less 0x05: 1 min or less 0x06: 5 min or less 0x07: 30 min or less
VerifyIntv	Uint2	This value is the link verification interval from the Hello Command message divided by 2.5.

2.2.3 Hello Request Message (MsgType 0x0e)

A one-way message used to trigger a Hello transaction from the recipient. Use this message to initiate communication with a node when the address of the node is not known.   If the application receives a Hello Request message from a datalogger, the best course of action is to return a Hello Message to the datalogger.

Hello Request Message Format (MsgType 0x0e):

Name	Type	Description
MsgType	Byte	Message type code (0x0e)
TranNbr	Byte	Transaction number (always zero)

2.2.4 Bye Message (MsgType 0x0d)

The Bye Message is a one-way message that lets a node on the network know that the link is shutting down and that the nodes will no longer be able to talk to each other. Before shutting down a link, like a phone modem connection, it is good practice to always send a Bye Message.

Bye Message Format (MsgType 0x0d):

Name	Type	Description
MsgType	Byte	Message type code (0x0d)
TranNbr	Byte	Transaction number (always zero)

2.2.5 Get/Set String Settings Transactions (MsgType 0x07, 0x87, 0x08, 0x88)

Both the Get Settings and Set Settings transactions are used exclusively when reading or writing settings in a CR200 series datalogger but only has limited usage for settings within a CR1000 type datalogger. These datalogger settings exist as a list of ASCII text variables within the datalogger and are used by the datalogger like environment variables are used by a personal computer.

Get Settings Command Message (MsgType 0x07):

Name	Type	Description
MsgType	Byte	Message type code (0x07)
TranNbr	Byte	Transaction number
NameList	ASCIIZ	List of names for which you want values. The names will be separated with an ASCII semi-colon character. If this is an empty string, the datalogger will respond with all settings.

Get Settings Response Message (MsgType 0x87):

Name	Type	Description
MsgType	Byte	Message type code (0x87)
TranNbr	Byte	Transaction number
Settings	ASCIIZ	A string containing a list of name-value pairs with each name separated by the value with the “=” sign. Each value-pair is separated with a semi-colon. For example: Model=CR200;PakBusAddress=1;

Set Settings Command Message (MsgType 0x08):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x08)
TranNbr	Byte	Transaction number
Settings	ASCIIZ	A string containing a list of name-value pairs with each name separated by the value with the "=" sign. Each value-pair is separated with a semi-colon. For example: Model=CR200;PakBusAddress=1;

Set Settings Response Message (MsgType 0x88):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x88)
TranNbr	Byte	Transaction number
RespCode	Byte	Response code: 0x00: Complete 0x01: Read-only 0x02: Out of space 0x03: Syntax error 0x04: Access denied
{ FailOffset }	UInt2	Offset from the start of the settings string to the name of the variable that caused the command to be rejected.

If a list of variables is specified while using the Set Settings transaction, the datalogger will process the settings one at a time until it finishes or until a setting fails to process. When a failure occurs, the response message will report the offset into the settings string where the offending setting starts. All settings up to the offending one are acceptable but the settings after the offending setting have not been evaluated by the datalogger.

Some examples of possible settings include:

- Model: The datalogger model name or number
- Version: The version of the datalogger
- SerialNbr: The serial number of the datalogger
- PakBusAddress: The PakBus address of the datalogger

2.2.6 DevConfig Transactions

Applications should use the DevConfig transactions to get settings from and set settings in a CR1000 type datalogger. The DevConfig transactions are a subset of the PakCtrl protocol.

Settings are variables within the operating system of a datalogger that control operation and can be changed by the user. An application using DevConfig transactions can obtain the values for these settings and change these settings if necessary.

As datalogger operating systems are revised, these settings may change or be removed. However, the datalogger will always report the major version number within the setting response message so that an application can be aware of the current operating system in the datalogger. By knowing the data type and version number, an application can verify the most current settings for a datalogger with the CR1000 Device Description File located in the Appendix of this document. Specific setting IDs can be gleaned from the Device Description file and used during the creation of an application that communicates with a CR1000 type datalogger.

2.2.6.1 DevConfig Get Settings Message (MsgType 0x0f & 0x8f)

The Get Settings transaction allows an application to receive all or part of the datalogger settings. The application sends a command and waits for the response from the datalogger. If the datalogger has more settings to send than can fit in a single response message, the MoreSettings parameter is set in the response. The application must issue another Get Settings message and specify the BeginSettingId to get the remaining datalogger settings.

DevConfig Get Settings Command (MsgType 0x0f):

Name	Type	Description
MsgType	Byte	Message type code (0x0f)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	The security code of the datalogger
{ BeginSettingId	UInt2	Allows the application to specify the first setting for the datalogger to include in the response message.
{ EndSettingId }}	UInt2	Allows the application to specify the last setting the datalogger should include in the response message.

DevConfig Get Settings Response (MsgType 0x8f):

Name	Type	Description
MsgType	Byte	Message type code (0x8f)
TranNbr	Byte	Transaction number
Outcome	Byte	Specifies the outcome of the transaction: 0x01: The transaction succeeded and values will follow 0x02: The security code is invalid
{ DeviceType	UInt2	Specifies a code that identifies the type of device that is sending the response: 0x0c: CR1000 type datalogger
MajorVersion	Byte	Identifies the version number for the device. The application can use a combination of the DeviceType and MajorVerion to identify the settings that should be supported by the device through the Device Description XML file.
MinorVersion	Byte	Identifies the version number to determine how settings for a device are to be interpreted. For example, a device might support a different baud rate in one version than in another version.

Name	Type	Description
MoreSettings	Boolean	Set to true by the datalogger when it has more settings to send than are in this response message
{ SettingId	UInt2	Identifies the specific setting being described
LargeValue	bit 15	Set to 1 if the setting value is larger than will fit into the 988 byte packet size limit for a DevConfig protocol packet
ReadOnly	bit 14	Set to 1 if this setting is read only
SettingLen	bit 13..0	Specifies the length in bytes of the setting that will follow. If LargeValue is set to true, the value that follows will be the first fragment of the message and subsequent fragments must be retrieved using the DevConfig Get Setting Fragment transaction.
SettingValue }}	Byte [1..988]	The value of the setting. The Binary format of this field depends on the setting type declared in the Setting Id parameter.

2.2.6.2 DevConfig Set Settings Message (MsgType 0x10 & 0x90)

The Set Settings transaction allows an application to change the value of one or more settings in the datalogger. The application sends the command message and waits for the datalogger's response message. The datalogger will not activate the new setting until the client sends a Control message to commit the setting. The datalogger will timeout after forty seconds and resume normal operations based on previous settings if it has not received an additional Set Settings command or a commit message.

DevConfig Set Settings Command (MsgType 0x10):

Name	Type	Description
MsgType	Byte	Message type code (0x10)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	The security code of the datalogger
{ SettingId	UInt2	The identity of the setting that follows
SettingLen	UInt2	The length in bytes of the SettingValue
SettingValue }	Byte [ ]	The value for the setting

DevConfig Set Settings Response (MsgType 0x90):

Name	Type	Description
MsgType	Byte	Message type code (0x90)
TranNbr	Byte	Transaction number
Outcome	Byte	The outcome of the transaction: 0x01: The transaction succeeded 0x02: The security code is invalid or does not provide sufficient access to set settings 0x03: Another client has already made changes that have not been committed
{ SettingId	UInt2	The setting identifier from the Set Settings command

Name	Type	Description
SettingsOutcome }	Byte	Specifies the outcome of the set attempt: 0x01: Setting value tagged to be changed 0x02: Setting identifier was not recognized 0x03: Setting value malformed or out of range 0x04: Setting is read-only 0x05: Not enough memory to store the setting

2.2.6.3 DevConfig Get Setting Fragment Transaction Message (MsgType 0x11 & 0x91)

The Get Setting Fragment transaction allows an application to ask for part of a setting value. This transaction is used if the setting value is too large for a single packet. Typically, an application will use the Get Settings transaction to retrieve a setting. However, if the LargeValue flag is set, the application can get the rest of the setting value using this transaction.

DevConfig Get Setting Fragment Command (MsgType 0x11):

Name	Type	Description
MsgType	Byte	Message type code (0x11)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	The security code of the datalogger
SettingId	UInt2	The identifier of the setting value that should be returned
Offset	Uint4	The offset from the start of the setting value where the requested fragment should start

DevConfig Get Setting Fragment Response (MsgType 0x91):

Name	Type	Description
MsgType	Byte	Message type code (0x91)
TranNbr	Byte	Transaction number
Outcome	Byte	The outcome of the transaction: 0x01: The transaction succeeded and the values will follow 0x02: The security code is invalid or does not provide sufficient access to read the setting 0x03: The transaction is not supported by this device
{ MoreFragments	bit 15	If set to true, there are more fragments that can be sent for this setting
FragmentSize	bits 14..0	The size of this fragment in bytes
FragmentData }	Byte [ ]	The fragment of the setting

2.2.6.4 DevConfig Set Setting Fragment Transaction Message (MsgType 0x12 & 0x92)

The Set Setting Fragment Transaction is used to send settings to the datalogger that are too large to fit in a single packet.

DevConfig Set Setting Fragment Command (MsgType 0x12):

Name	Type	Description
MsgType	Byte	Message type code (0x12)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	The security code of the datalogger
SettingId	UInt2	The identifier of the setting value that should be returned
FragmentOffset	UInt4	The starting offset for this fragment
MoreFragments	bit 15	If set to true, the application has more fragments to send for this setting
FragmentLen	bits 14..0	The length in bytes of the setting value to follow
FragmentData	Byte [ ]	The setting fragment data

DevConfig Set Setting Fragment Response (MsgType 0x92):

Name	Type	Description
MsgType	Byte	Message type code (0x92)
TranNbr	Byte	Transaction number
Outcome	Byte	The outcome of the transaction: 0x01: The setting value was tagged for change or the fragment was accepted 0x02: The security code is invalid or does not provide sufficient access to set settings 0x03: The setting identifier was not recognized 0x04: The setting value was malformed or out of range 0x05: The setting is considered read-only 0x06: Not enough memory to store the setting 0x07: This device does not support this transaction

2.2.6.5 DevConfig Control Transaction Message (MsgType 0x13 & 0x93)

The Devconfig Control transaction controls what the datalogger does with the settings it has in memory. The application uses this transaction to tell the datalogger to commit changes to permanent storage, cancel any changes, revert all settings to the device defaults, or refresh the session timer.

The datalogger has a forty-second session timer that gets set or reset each time a valid message is received from the client. When this timer expires, the datalogger will rollback any changes that have not been committed.

DevConfig Control Command (MsgType 0x13):

Name	Type	Description
MsgType	Byte	Message type code (0x13)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	The security code of the datalogger

Name	Type	Description
Action	Byte	The action that should be taken by the datalogger 0x01: Commit the changes and exit 0x02: Cancel any changes and exit back to a mode where a new session can be started 0x03: Revert all settings to factory defaults. Note that these settings will not take effect until they are committed with another instance of this transaction 0x04: Don't do anything with the setting at present but refresh the session timer 0x05: Cancel any changes and reboot the datalogger

DevConfig Control Response (MsgType 0x93):

Name	Type	Description
MsgType	Byte	Message type code (0x93)
TranNbr	Byte	Transaction number
Outcome	Byte	The outcome of the transaction: 0x01: The settings will be committed and the device rebooted 0x02: The security code is invalid or does not provide sufficient access to set settings 0x 03: There are no changes to commit and the session is ending 0x04: The changed settings will be discarded and the device will be rebooted 0x05: The settings have reverted to device defaults but must be committed to take effect 0x06: The session timer has been reset 0x07: The specified action cannot be carried out because another client has already made changes to the settings for this device

2.3 BMP5 Application Packets

BMP5 application packets are framed with a PakBus SerSyncByte, 0xbd, and use the standard eight-byte PakBus header that was used in the PakCtrl messages. The only difference in the header is the value of the HiProtoCode parameter. PakCtrl messages have a HiProtoCode parameter of zero while the header for a BMP5 message has a HiProtoCode parameter of one.

The following are the BMP5 packet types that are necessary for communication. Keep in mind the general structure of a complete PakBus packet since the following BMP5 packet type descriptions will only contain information regarding the message type, transaction number and body of the packet.

2.3.1 Please Wait Message (MsgType 0xa1)

If the datalogger anticipates it will take more than the default one second to produce a response after receiving a command, a Please Wait message will be sent to the client indicating the amount of time the client should wait for a response to that command. The transaction number of the Please Wait message will be the same as the command packet on which it is waiting.

After the Please Wait message has been sent, the datalogger will send the normal transaction response as soon as it is ready. If the datalogger determines that the response will still take longer than the wait time it just sent, the datalogger will send another Please Wait message to the application before the current wait time expires.

Please Wait Message Body (MsgType 0xa1):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0xa1)
TranNbr	Byte	Transaction number
CmdMsgType	Byte	MsgType of the command on which we are waiting
WaitSec	UInt2	Number of seconds to wait for a response (30 second limit).

2.3.2 Clock Transaction (0x17 & 0x97)

The clock transaction can be used to check the current time or to adjust the datalogger clock. Note the inherent danger of retrying a clock set command. If the client were to simply retry a failed clock set attempt without knowing whether the first try reached the station, there is a danger the clock will be changed more than wanted. If a clock set attempt fails, the client should read the clock again to determine whether additional adjustments are needed.

Clock Command Body (MsgType 0x17):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x17)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	Security code for the datalogger
Adjustment	Nsec	Quantity of time to add to the clock. If the datalogger clock is ahead of the current time, the Adjustment field should be negative.

Clock Response Body (MsgType 0x97):

Name	Type	Description
MsgType	Byte	Message type code (0x97)
TranNbr	Byte	Transaction number
RespCode	Byte	Response code: 0x00: Complete 0x01: Permission denied
{ OldTime }	Nsec	Difference between the datalogger clock and January 1, 1990. This field is not returned unless RespCode is zero.

2.3.3 File Transfer and Control Transactions

File transfer and control transactions are used to list datalogger directories, download datalogger programs, upload datalogger programs, obtain table definitions, and administer data files. These functions are accomplished by downloading files to or uploading files from the datalogger and by executing file control operations on those files. The specific message types are:

2.3.3.1 File Download Transaction (MsgType 0x1c & 0x9c)

This transaction moves a file from the client application to the datalogger. If the file is larger than the allowed message size, the client application should separate the file into fragments, which is called a multiple exchange transaction. The transaction number must be the same for all file message fragments since the datalogger uses this number to keep track of entire file during the transaction. The CloseFlag field listed in the description below is used to mark the end of the multiple exchange transaction.

The CR200 datalogger has limited memory resources and can not receive a standard 1000 byte PakBus message. The CR200 dataloggers advertise the maximum packet size in a device setting called “MaxPktSize” that can be obtained with the PakCtrl Get Settings transaction. This setting must be used to adjust the size of the File Download Command message. If a device does not specify the MaxPktSize setting, the standard 1000-byte PakBus message size is the limit.

File Download Command Body (MsgType 0xlc):

Name	Type	Description
MsgType	Byte	Message type code (0x1c)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	Security code of the datalogger
FileName	ASCIIZ [0..64]	The file name and the device where the file will be stored. This field may be null after the first exchange of a multiple fragment transaction.
Attribute	Byte	A reserved byte that the application must currently designate as 0x00.
CloseFlag	Byte	0x00: Keep the file open for more exchanges 0x01: This is the final or only exchange of this transaction.

Name	Type	Description
FileOffset	UInt4	Describes the byte offset into the file of this fragment. This field will be zero if this is a single exchange transaction.
{ FileData }	Byte [ ]	The data being sent in this packet

File Download Response Body (MsgType 0x9c):

Name	Type	Description
MsgType	Byte	Message type code (0x9c)
TranNbr	Byte	Transaction number
RespCode	Byte	Response Code: 0x00: Complete 0x01: Permission denied 0x02: Insufficient resources or memory full 0x09: Invalid fragment number 0x0d: Invalid file name 0x0e: File is not currently accessible
FileOffset	UInt4	The FileOffset number from the command packet to which this is responding

2.3.3.2 File Upload Transaction (MsgType 0x1d & 0x9d)

This transaction moves a file from the datalogger to the client application. The CloseFlag field, listed in the description below, closes the file and indicates the End of File. If an attempt to read past the End of File occurs, the datalogger provides a final response indicating FileData empty and automatically closes the file without requiring any additional exchanges.

File Upload Command Body (MsgType 0x1d):

Name	Type	Description
MsgType	Byte	Message type code (0x1d)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	Security code for the datalogger
FileName	ASCIIZ [0..64]	The name of the file to be retrieved
CloseFlag	Byte	0x00: Keep the file open for more exchanges on this transaction 0x01: This transaction is the final exchange of the transaction
FileOffset	UInt4	Byte offset into the file of the fragment
Swath	UInt2	The number of bytes to read

File Upload Response Body (MsgType 0x9d):

Name	Type	Description
MsgType	Byte	Message type code (0x9d)
TranNbr	Byte	Transaction number

Name	Type	Description
RespCode	Byte	Response Code: 0x00 – Complete 0x01 – Permission denied 0x0d – Invalid file name 0x0e – File is not currently accessible
FileOffset	UInt4	Byte offset into the file of this fragment
{ FileData }	Byte [ ]	The file data beginning at FileOffset. If an attempt was made to read past the end of the file, then this field will be empty or smaller than size requested in the Swath parameter of the command message.

2.3.3.3 File Directory Format

Old programs and other files can be stored in the memory of the CR1000 type datalogger. To obtain a list of the files maintained in a CR1000 type datalogger, use the File Upload transaction and specify a file named ".DIR". A directory listing of the files being stored on the datalogger will be returned. The file received in the response message has the following format:

Directory File Format:

Name	Type	Description
DirVersion	Byte	File format version
{ FileName	ASCIIZ [1..64]	File name
FileSize	UInt4	File size in bytes
LastUpdate	ASCIIZ	Date of the last file update
{ Attribute }	Byte [0..12]	File attribute code. This field may repeat up to 12 times to specify a list of file attributes. 0x01: Running now 0x02: Run on power-up 0x03: Read only 0x04: Hidden 0x05: Program execution paused
0x00 }	Byte	File attribute list terminator

2.3.3.4 File Control Transaction (MsgType 0x1e & 0x9e)

The File Control transaction controls compilation and execution of the datalogger program and manages the files on the datalogger

File Control Command Body (MsgType 0x1e):

Name	Type	Description
MsgType	Byte	Message type code (0x1e)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	Security code of the datalogger
FileName	ASCIIZ [1..64]	File name and device where the file exists. For example, "CPU:CR1000Program.CR1".

Name	Type	Description
FileCmd	Byte	Code that specifies the command to perform with the file: 0x01: Compile and run the program and also make it the “run on power-up” file 0x02: Set the “run on power-up” attribute. When used with an empty file name argument, the “run on power-up” attribute will be cleared. 0x03: Make this file hidden 0x04: Delete this file 0x05: Format the device 0x06: Compile and run the file without deleting the data tables 0x07: Stop the running program 0x08: Stop the running program and delete the associated files 0x09: Make this file the new datalogger OS 0x0a: Compile and run the program without changing the “run on power-up” attribute 0x0b: Pause running program execution 0x0c: Resume running program execution 0x0d: Stop the currently running program, delete associated data files, run the specified file, and set it to “run on power-up”. 0x0e: Stop the currently running program, delete associated files, run the specified file, but don’t change the “run on power-up” setting

File Control Response Body (MsgType 0x9e):

Name	Type	Description
MsgType	Byte	Message type code (0x9e)
TranNbr	Byte	Transaction number
RespCode	Byte	0x00 – Complete 0x01 – Permission denied 0x0d – Invalid file name 0x13 – Unsupported FileCmd code
HoldOff	UInt2	Number of seconds the client should wait before attempting the next transaction.

The steps of a complete File Control transaction are shown in this explanation of a CR200 series datalogger program download:

1. Use a File Control command to stop the running program and delete associated files to make room for the new program

2. Use File Download to send the new program to the datalogger

3. Use a File Control command to compile and run the new program

4. Use Get Programming Statistics to obtain the compile results

2.3.3.5 Get Programming Statistics Transaction (MsgType 0x18 & 0x98)

The Get Programming Statistics transaction retrieves available status information from the datalogger.

Get Programming Statistics Command Body (MsgType 0x18):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x18)
TranNbr	Byte	Transaction number
Security Code	UInt2	Security code of the datalogger

Get Programming Statistics Response Body (MsgType 0x98):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x98)
TranNbr	Byte	Transaction number
RespCode	Byte	Response Code: 0x00: Complete 0x01: Permission denied
{ OSVer	ASCIIZ	Datalogger operating system version
OSSig	UInt2	Datalogger operating system signature
SerialNbr	ASCIIZ	Datalogger serial number
PowUpProg	ASCIIZ	Name of the “run on power-up” program
CompState	Byte	Compile and execution status: 0x00: No datalogger program 0x01: Datalogger program running 0x02: Program cannot compile 0x03: Program is paused
ProgName	ASCIIZ [1..64]	Datalogger program name
ProgSig	UInt2	Datalogger program signature
CompTime	NSec	Time when program was compiled relative to January 1, 1990.
CompResult }	ASCIIZ [0..250]	Compilation result text that exist as one or more carriage return and line feed separated lines of ASCII characters with null termination after the last line

2.3.4 Data Collection and Table Control Transactions

2.3.4.1 Table Definitions

Since dataloggers store data in tables, the datalogger and the application must understand and agree on the structure of each table in order to collect data. Table definitions contain the parameters that describe each table, record, and field in the datalogger and are contained in a file on the datalogger with a “.TDF” file extension.

Table definitions are used by the application to know what tables and fields exist and what data to expect from each table when collecting values from the datalogger. The table definitions specifically describe the data tables, records, and fields that have been established by the program in the datalogger. These table definitions are necessary to calculate the table signature for the Collect

Data transaction and to describe what data should be returned when collecting data from a datalogger.

2.3.4.2 Getting Table Definitions and Table Signatures

Table definitions are obtained using a File Upload transaction and are contained in a file with a ".TDF" file extension. The application only needs to specify the name ".TDF" and the datalogger will recognize this file extension in the command message and return the appropriate response containing the table definitions. The format of the ".TDF" file is shown in the following table:

Table Definitions File Format:

Name	**Type**	**Description**
FslVersion	Byte	File format version. (Use 0x01)
{ TableName	ASCIIZ	Table Name
Table Size	UInt4	Number of records allocated in the datalogger for this table
TimeType	Byte	Data type code of the "Time Tag" field
TblTimeInto	NSec	"Time Into" part of the "Time Into Interval" for the table interval
TblInterval	NSec	"Interval" part of the table interval (zero means an event driven table)
{ ReadOnly	bit 7	0: Read/Write 1: Read-only
FieldType	bits 6..0	Data type of the field
FieldName	ASCIIZ	Name of the field in the table
{ AliasName }	ASCIIZ	Alias or "FieldName" assigned to the elements within this field. Currently not used.
(0)	Byte	Alias names list terminator
Processing	ASCIIZ	Generated by the datalogger, this string designates the type of processing and processing parameters used to generate this field (i.e. "Max", "Min", "Avg", "Tot", etc.).
Units	ASCIIZ	Field units
Description	ASCIIZ [0..80]	Description of the field
BegIdx	UInt4	Beginning index. The array index number for the first element of the array (1 by default or if not an array).
Dimension	UInt4	Array dimension of the whole array (set to 1 if not an array)
{ SubDim }	UInt4	Sub-dimension of a multidimensional array
(0) }	UInt4	Sub-dimension list terminator
(0) }	Byte	Field list terminator

There are three implied parameters that are part of the table definitions: Table Numbers, Field Numbers, and the Table Definition Signature. Table Number one is the first table. Field Number one is the first field that follows the Time Tag. Table and Field Numbers are important because they are often used to specify the location of data in the datalogger in other commands.

In order to ensure the integrity of this table information, the application should calculate a signature of the parameters contained in each table within the table definitions. One signature should be calculated for each defined table and should be stored and used by the application to verify that the table has not changed when collecting data.

The signature is calculated using the parameters for each table from the Get Table Definitions response. For each table, calculations start with the first byte of the Table Name and end after the Field List Terminator of that table. A description of the algorithm used to calculate the signature along with example code is found in Appendix B. The Table Definition Signature is used to verify that table definitions have not changed on the datalogger while data collection operations continue.

2.3.4.3 Collect Data Transaction (MsgType 0x09 & 0x89)

The Collect Data Transaction is used to collect records from the datalogger.

Collect Data Command Body (MsgType 0x09):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x09)
TranNbr	Byte	Transaction number
Security Code	UInt2	Security code of the datalogger
CollectMode	Byte	Collection mode code: 0x03: Collect from the oldest record in each table and collect to the newest record. 0x04: Collect from “P1” to the newest record. If the start record “P1” does not exist and is not the next record that will be stored, collect will start from the oldest record in each table. 0x05: Collect the most recent records where “P1” designates how many records to collect. 0x06: Collect records that lie between “P1” and “P2”. Include “P1” but exclude “P2”. If no records exist between “P1” and “P2”, an empty data response will be sent. 0x07: Collect a Time Swath where “P1” and “P2” are the time parameters (NSec relative to Jan 1, 1990). Get all records with time tags greater than or equal to “P1” and less than “P2”. 0x08: Collect a partial record when the record size has exceeded the maximum packet size. “P1” specifies the record number and “P2” specifies the byte offset into the record that was partially retrieved.
{ TableNbr	UInt2	Table number
TableDefSig	UInt2	Table definition signature
{ P1 }	UInt4 or NSec	Parameter used to specify what to collect
{ P2 }	UInt4 or NSec	Optional parameter used to specify what to collect
{ FieldNbr }	UInt2	Field number or an empty list to specify all fields
(0) }	UInt2	Field list terminator

When a response comes in from this command, the fields after RespCode exist only if the response indicates the transaction completed. If the response to the Collect Data Command sets the parameter IsOffset equal to one, the client must retrieve the remaining fragments of the record by using collect mode 0x08. The client should know the size of the record and therefore know when the entire record has been collected.

Collect Data Response Body (MsgType 0x89):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x89)
TranNbr	Byte	Transaction number
RespCode	Byte	Response code: 0x00: Completed 0x01: Permission denied 0x02: Insufficient resources 0x07: Invalid table definition
{ { TableNbr	UInt2	Table number
BegRecNbr	UInt4	The first record number from the table
IsOffset	bit 7	A flag that, if true, indicates this message contains a fragment of a single record.
NbrOfRecs	15 or 31 bits	Number of Records (15-bit value) in RecFrag field or if IsOffset is true, it is the byte offset (31-bit value) into the current record where this fragment starts. The offset is based from the beginning of the TimeOfRec field.
{ TimeOfRec }	Sec, USec, or NSec	Time of the first record relative to Jan 1, 1990. This field only exists for interval data and also only exists on the first fragment of a fragmented record. The table definition interval will be non-zero.
RecFrag }	Byte [ ]	Records as specified by the collection parameters or if the IsOffset field is true, this is a fragment of a record. Note: a time field exists preceding each record on event driven data, and the table definition interval is zero.
MoreRecsExist }	Bool	More records or fragments exist. Since the datalogger may limit the response message size to the larger of 512 bytes or one record, sometimes not all of the requested records can be returned in a single response. If more records exist that meet the criteria of the collection parameters than are returned from the datalogger, this flag will be set.

2.3.4.4 One-Way Data Transaction (MsgType 0x20 & 0x14)

One-way data messages provide a way for a datalogger to send records to an application when the underlying network has either limited or no support for two-way communication. These one-way data messages may also be used to emit data to an application during an event or on a regular schedule. One-way data messages are initiated and controlled completely by the datalogger program. The application must recognize these packets as they are received from the datalogger and handle them appropriately.

Table definitions may be sent from the datalogger to the application prior to the first transmission of a one-way data message and periodically thereafter. Use the table definitions to calculate the table signatures for each table in the same manner as the standard data collection process. The table definition signature is always included in the one-way data message as an independent verification that the table definitions have not changed since they were last received. Since these one-way data messages exist outside of any transaction, the transaction number will always be zero.

One-Way Table Definition Message Body (MsgType 0x20):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x20)
TranNbr	Byte	Transaction number
TableNbr	UInt2	Table number
TableName	ASCIIZ	Table name
TableSize	UInt4	Number of records allocated in the datalogger for this table
TimeType	Byte	Data type code of the Time Tag field
TblTimeInto	Nsec	“Time Into” part of the “Time Into Interval” for the table interval
{ ReadOnly	bit 7	0: Read/Write 1: Read only
FieldType	bits 6..0	Data type of the field
FieldName	ASCIIZ	Name of the field within the table
{ AliasName }	ASCIIZ	Alias or “FieldName” assigned to the elements within this field. Currently not used.
(0)	Byte	Alias names list terminator
Processing	ASCIIZ	Designates the type of processing and processing parameters used to generate this field (i.e. “Max”, “Min”, “Avg”, “WndVec”, etc.). This field provides information necessary to display data, for example, if this field were a histogram, the parameters might include the name, units, and dimensions of the other axis for graphing.
Units	ASCIIZ	Field units
Description	ASCIIZ [0..80]	Description of the field
BegIdx	UInt4	Beginning index. The array index number that for the first element of the array (1 by default or if not an array).
Dimension	UInt4	Array dimension of the whole array (set to 1 if not an array)
{ SubDim }	UInt4	Sub-dimension of a multidimensional array
(0) }	UInt4	Sub-dimension list terminator
(0)	Byte	Field list terminator

One-Way Data Message Body (MsgType 0x14):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x14)
TranNbr	Byte	Transaction number
TableNbr	UInt2	Table number
TableDefSig	UInt2	Table definition signature
RecNbr	UInt4	Record number of this record
IsOffset	bit 7	A flag that, if true, indicates this message contains a fragment of a single record.
NbrOfRecs	15 or 31 bits	Number of Records (15-bit value) in the RecFrag field or if the parameter IsOffset is true, it is the byte offset (31-bit value) into the current record where this fragment starts. The offset is based from the beginning of the TimeOfRec field.
{ TimeOfRec }	Sec, USec, or NSec	Time of the first record relative to Jan 1, 1990. This field exists for interval data but only exists on the first fragment of a fragmented record.
RecFrag	Byte [ ]	Records as specified by the collection parameters or if the IsOffset field is true, this is a fragment of a record. Note: A time field exists preceding each record on event driven data.

2.3.4.5 Table Control Transaction (MsgType 0x19 & 0x99)

Use this transaction to administer tables in the datalogger.

Table Control Command Body (MsgType 0x19):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x19)
TranNbr	Byte	Transaction number
Security Code	UInt2	Security code of the datalogger
CtrlOption	Byte	Control option code: 0x01: Reset the table and trash existing records 0x02: Roll over to a new file if the tables are managed in files

Table Control Response Body (MsgType 0x99):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x99)
TranNbr	Byte	Transaction number
RespCode	Byte	Response Code: 0x00: Complete 0x01: Permission denied 0x0f: Option not applicable 0x10: Invalid table name

2.3.5 Get/Set Values Transaction (MsgType 0x1a, 0x9a, 0x1b, & 0x9b)

These transactions are used to read or write values in the datalogger table. Values are referenced by table and field name. The table definitions can be used to get table and field names from a datalogger if they are not known.

Get Values Command Body (MsgType 0x1a):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x1a)
TranNbr	Byte	Transaction number
Security Code	UInt2	Security code of the datalogger
TableName	ASCIIZ	Table name
TypeCode	Byte	Data type code that specifies the format of the data values returned in the response
FieldName	ASCIIZ	Field name including dimensionality if applicable
Swath	UInt2	Number of values to get starting with the one specified by FieldName

Get Values Response Body (MsgType 0x9a):

Name	**Type**	**Description**
MsgType	Byte	Message type code (0x9a)
TranNbr	Byte	Transaction number
RespCode	Byte	Response code: 0x00: Complete 0x01: Permission denied 0x10: Invalid table or field 0x11: Data type conversion not supported 0x12: Memory bounds violation
{ Values }	Byte [ ]	Values from the datalogger repeated as needed according to the Swath. The TypeCode and the number of elements requested determine the size of this field.

Set Values Command Body (MsgType 0x1b):

Name	Type	Description
MsgType	Byte	Message type code (0x1b)
TranNbr	Byte	Transaction number
SecurityCode	UInt2	Security code of the datalogger
TableName	ASCIIZ	Table name
TypeCode	Byte	Data type code that specifies the format of the data values returned in the response
FieldName	ASCIIZ	Field name including dimensionality if applicable
Swath	UInt2	Number of values to set starting with the one specified by FieldName
{ Values }	Byte [ ]	Values to set in the datalogger repeated as needed according to the Swath. The TypeCode and the number of elements requested determine the size of this field.

Set Values Response Body (MsgType 0x9b):

Name	Type	Description
MsgType	Byte	Message type code (0x9b)
TranNbr	Byte	Transaction number
RespCode	Byte	Response code: 0x00: Complete 0x01: Permission denied 0x10: Invalid table or field 0x11: Data type conversion not supported 0x12: Memory bounds violation

Since dealing with data types can be a complex process in these transactions, the client application will dictate the data type. On a Get Values transaction the datalogger must convert the values to the data type requested. On a Set Values transaction, the datalogger must convert the values to the appropriate internal data type. If a conversion is not supported or not possible, the response will indicate this lack of support appropriately.

Section 3. The CR200 Datalogger

The CR200 is low-cost, rugged, and versatile measurement device. This small datalogger contains a CPU and both digital and analog inputs and outputs. The CR200 has a PakBus operating system that communicates via the BMP5 message protocol. Pre-compiled programs sent to the datalogger are written in a BASIC-like language that includes data processing and analysis routines. These programs run on a precise execution interval and will store measurements and data in tables.

The CR200 has a built in RS-232 port allowing a direct connection from a PC. Once the PC has established a connection to the datalogger, the application running on the PC can communicate directly to the datalogger. Unlike other dataloggers the CR200 does not have security available in the operating system. Since a security code cannot be set in the CR200, the SecurityCode field prevalent in many of the BMP5 protocol message bodies can remain null.

3.1 Dealing with Unexpected, Asynchronous Commands from the CR200

Communication on a packet switched network occurs asynchronously. Therefore, an application must not expect response packets from the datalogger in any particular order. Careful attention to each transaction number and message type will help eliminate confusion with packets that are received by the application. In addition, the DstPhyAddr value in the header of each received packet should match the application's advertised address or the packet should be discarded.

There also may be packets and message types periodically sent across the network that aren't detailed in this document. This document attempts to describe the critical message types necessary to facilitate communication. If the application receives any packets from a datalogger that haven't been discussed in this documentation, the application should respond with a PakCtrl Delivery Failure Message (Packet Type 0x81) specifying that the command is not currently implemented or understood by the application.

3.2 Getting the Attention of the Datalogger

The application should initiate communication with the datalogger by using a SerPkt Link-state "Ring" transaction. The datalogger will return a SerPkt Link-state "Ready" packet to let the application know to proceed with communication. Although the initial Ring and Ready packets should be used, they are not required. If the PakBus address of the datalogger is known, the application can send any appropriate message to the datalogger at anytime.

An example of a "Ring" packet from an application with a PakBus address of 4094 to a datalogger with a PakBus address of 1 to request the communication link state is as follows:

```
BD 90 01 0F FE 71 D2 BD
```

An example of a "Ready" response from a datalogger with an address of 1 to an application with an address of 4094 letting the application know it can proceed with communication is as follows:

```
BD AF FE 00 01 5A 89 BD
```

The datalogger may not be aware that a connection has been established from the PC when beginning the initial communication process. The application should initiate communication to the CR200 by sending a series of 0xbd SerSyncBytes to wake up the datalogger and clear the communication buffer. The CR200 series datalogger only supports connections at 9600 baud.

3.3 Getting the PakBus Address of the CR200

The address of the CR200 datalogger is necessary for communication. Every PakBus device needs a PakBus address to send and receive packets. In addition all devices on the network require unique addresses. The valid range for PakBus addresses is 1 to 4094. The address range of 1 to 3999 is normally reserved for dataloggers while the address range of 4000 to 4094 is normally reserved for applications. The CR200 ships with a default PakBus address of 1 but could have any address within the allowable range.

If the address of the CR200 datalogger is unknown, this information can be obtained with a PakCtrl Hello Request Message. Since all PakBus dataloggers on the network will respond to this broadcast type message, make sure you are connected to a single datalogger before you send a PakCtrl Hello Request Message in order to determine that specific datalogger's address.

The DstPhyAddr and DstNodeId in the header of the Hello Request Message should be specified as 4095 to indicate a broadcast packet. The datalogger will respond to the application with a Hello Command transaction that contains its PakBus address in the header.

3.4 Getting and Setting CR200 Settings

The settings within the CR200 datalogger are obtained with the Get Settings transaction. Similarly the CR200 settings can be set with the Set Settings transaction. The CR200 uses datalogger settings much like a personal computer uses environmental variables.

Datalogger settings exist as ASCII strings in the CR200. They are returned to the application in a response message as a string containing a list of name-value pairs with each name separated by the value with the "=" sign. Each value-pair is also separated with a semi-colon. For example:

```
Model=CR200;PakBusAddress=1
```

Some examples of available CR200 settings include:

- Model: The datalogger model name or number
- Version: The version of the datalogger
- SerialNbr: The serial number of the datalogger

- PakBusAddress: The PakBus address of the datalogger

If the names of the available settings are not known, all settings within the CR200 datalogger can be obtained by specifying a null NameList parameter in a Get Settings transaction. Once the settings are returned, they can be parsed, viewed, and later used as needed.

3.5 Getting and Setting the CR200 Clock

The CR200 datalogger contains an accurate clock that drives the execution interval of the running datalogger program. An application can either check or set the datalogger clock with the Clock Transaction.

Before attempting to set the datalogger clock, the application should always check the current time. Then, if necessary, the appropriate adjustment can be made by either adding time to or subtracting time from the datalogger clock with the Clock Command message. A hexadecimal example of this message that is checking the clock for a datalogger with a PakBus address of 1 looks like:

```
BD A0 01 4F FE 10 01 0F FE 17 17 00 00 00 00 00 00 00 00 00
00 B2 B3 BD
```

The response from the datalogger to the clock request comes in the form of the Clock Response message. A hexadecimal example of a clock response packet looks like:

```
BD AF FE 00 01 1F FE 00 01 97 17 00 1B FA 2A 61 C8 00 00 00
04 FA BD
```

3.6 Datalogger Program Structure

CR200 programs are written with a programming language called CRBasic. This BASIC-like programming language syntax facilitates the creation of datalogger programs capable of precise measurement and data analysis. Datalogger programs declare variables, define tables to store data, and run instructions to make measurements or process information.

Datalogger programs that are sent to the datalogger execute on a precise interval to process data or make measurements. Data are stored in tables defined by the datalogger program. By default, all CR200 dataloggers include the Status table and the Public table. The Status table contains information about the datalogger operating system and parameters. The Public table contains program variables and measurements. A maximum of four additional custom tables can be defined in the datalogger program and used to store data in the CR200.

When the datalogger runs the compiled program, the defined tables are created in Flash memory. As the program executes, data are stored in the created tables on the specified interval. Therefore, when the datalogger is powered down, the data remains. However, since the datalogger program creates the tables, all data are erased when a new datalogger program is sent to the datalogger.

3.7 Creating CR200 Programs and the CR200 Compiler

The CR200 datalogger must contain a valid program in order to execute instructions that measure and analyze sensor data. These programs are usually generated with either a software program called Short Cut for Windows or with a program editor called CRBasic Editor but if the correct syntax is used, datalogger programs can be written with any text editor.

Because of the compact size of the CR200, only compiled programs can be sent to the datalogger. Once a program has been created, it must be compiled to match the operating system of the datalogger before being sent to the CR200. If program compiler does not match the current operating system on the datalogger, the compiled program will be rejected.

Appropriate compilers are included with both Short Cut for Windows and the CRBasic Editor. Once an application discovers the operating system version of the CR200, the appropriate compiler can be used to compile a program before sending it to the datalogger. When a program is sent to the datalogger, the datalogger response will indicate if a compiler compatibility problem exists.

Attempts should be made to use the most recently released operating system in the CR200. However, if the program compiler and the datalogger operating system are not compatible, either the program must be recompiled with the correct compiler or the datalogger operating system must change to match the compiled program. Since there is not a an easy way to know what compiler was used on the datalogger program, the recommended resolution is to discover the operating system version of the CR200 and recompile the datalogger program with the corresponding compiler.

3.7.1 Discovering the CR200 OS Version

There are two methods of discovering the CR200 operating system version. The first method is to use the File Control Get Programming Statistics transactions to query the datalogger for this information. The datalogger operating system information will be included in the response message.

The second method is to get table definitions and then collect data from the Status table of the CR200. The Status table holds key information like the datalogger operating system version. However, if a program isn’t running on the datalogger, table definitions will not be available and the Status table cannot be queried. Therefore, the better option may be to focus on getting the OS version using the Get Programming Statistics transaction.

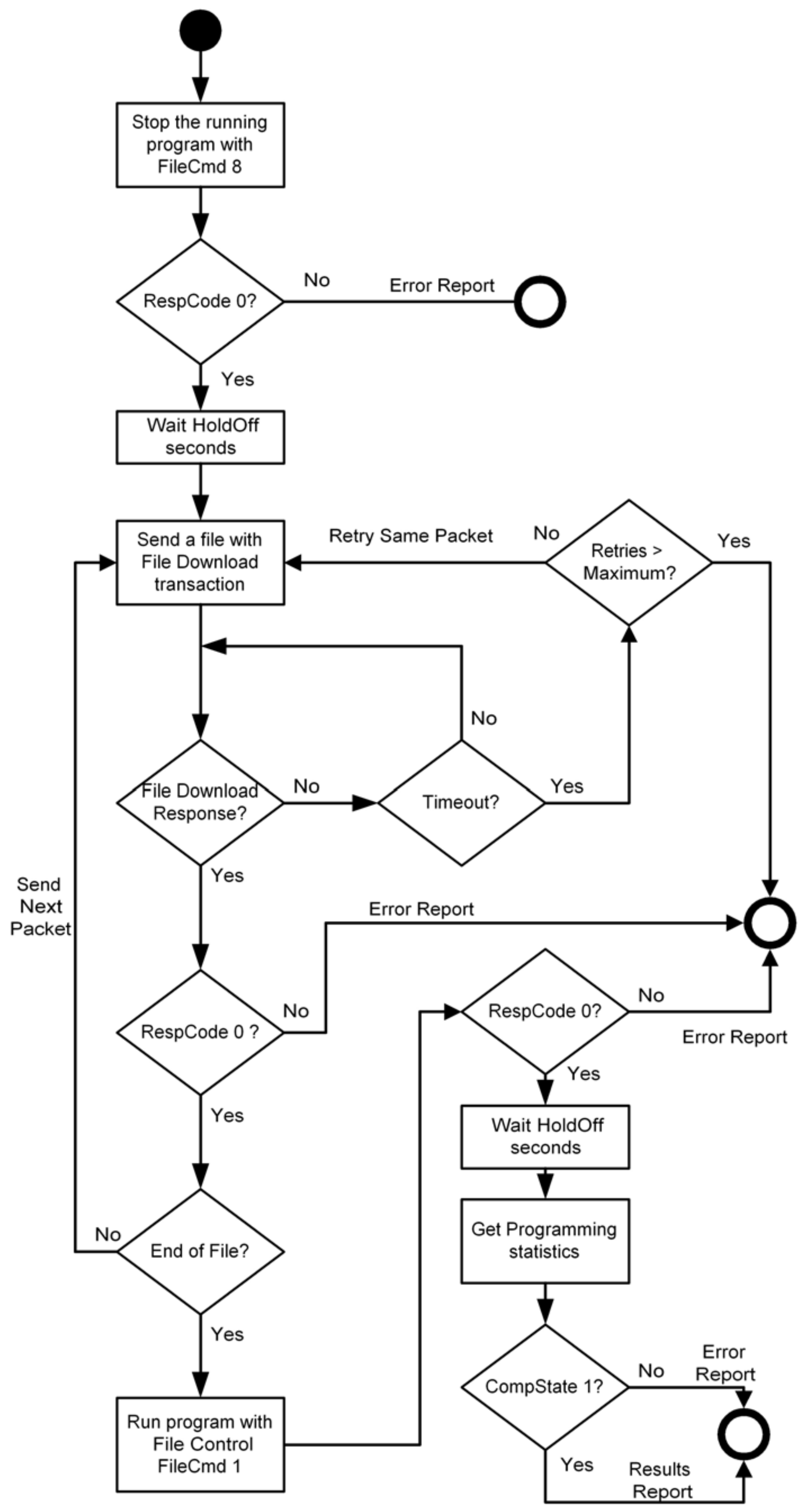
Compare the discovered CR200 series datalogger operating system version to the compiler used to create the datalogger program. For example, if the datalogger reports an operating system of “v03A”, the appropriate compiler would be named “cr2compv03A.exe”. Remember that the program must be compiled to match the operating system running on the datalogger.

3.7.2 Sending a Program to the CR200

The compiled datalogger program is sent to the CR200 with the File Download transaction. The FileName parameter of this transaction describes the file name and location in datalogger memory where the datalogger program should be stored. The compiled datalogger program will always have an extension of ".bin". An example of the FileName parameter is "CPU:CR200Program.bin".

In addition, the attributes of the file should be specified. With the CR200 the only file attribute to consider when sending the datalogger program is run now since the compact size of the datalogger disallows the storage of old programs or files.

The compact buffer size of the CR200 requires that the application not send a packet that exceeds 100 bytes including the header. If the datalogger program being sent exceeds this maximum size, the message must be broken across multiple packets. The complexity of sending a program to the datalogger is shown in the following diagram.


Stop the running program with FileCmd 8
RespCode 0?
No
Error Report
Yes
Wait HoldOff seconds
Send a file with File Download transaction
Retry Same Packet
No
Retries > Maximum?
Yes
No
File Download Response?
No
Timeout?
Yes
Yes
Send Next Packet
Error Report
RespCode 0 ?
No
RespCode 0?
No
Error Report
Yes
Yes
Wait HoldOff seconds
Get Programming statistics
No
End of File?
Yes
CompState 1?
No
Error Report
Run program with File Control FileCmd 1
Yes
Results Report

Use the File Control Command with a FileCmd parameter of 0x08 to stop the program currently running on the datalogger.

Check the File Control Response. If the RespCode returns a zero, determine the amount of time to wait as declared in the HoldOff parameter before continue the process. Otherwise, report and act on the error result.

Use the File Download Command message to send the new program file to the datalogger. The new program file must have the ".BIN" file extension. Usually the new program is larger than the 100-byte MaxPktSize of the CR200 datalogger so it should be separated into packets that will fit into the MaxPktSize. After sending each packet, the application should check the RespCode and FileOffset parameters for errors. The file download operation should stop immediately if an error occurs and the error should be handled. If a response is not received, the application can retry the same packet. If there are no problems, the packets should be sent in sequential order to the datalogger.

Use the File Control Command with the FileCmd parameter set to 1 to run the new program on the datalogger. Since the CR200 series datalogger does not contain a file system that allows storage of old programs or files, the only option really available at this step is to run the current program.

Check the File Control Response. If the RespCode returns a zero, determine the amount of time to wait as declared in the HoldOff parameter before continuing the process. Otherwise, report and act on the error message.

Finally, use the Get Programming Statistics transaction and obtain compile results to verify the new datalogger program information.

3.7.3 Interpreting the Response

After the compiled datalogger program has been sent, the application should receive a File Download Response message. The response code within this message indicates what action the application should attempt next. Possible response codes include: complete (0x00), permission denied (0x01), insufficient resources or memory full (0x02), invalid fragment number (0x09), invalid file name (0x0d), and file is not currently accessible (0x0e).

3.7.4 Handling Rejection

When everything goes as planned, the datalogger indicates the program was sent successfully with a response code of complete (0x00). However, if a problem occurs when sending a program, the datalogger will indicate the nature of the problem with the appropriate response code.

There have been cases where a "permission denied" message has been received from the CR200. Since security can not be enabled on the CR200, this message actually indicates that the Swath parameter of the requested packet exceeds the maximum PakBus packet size of 1000 bytes. The application should not request a packet size larger than the maximum from the datalogger in the Swath parameter of the File Upload Command message.

Finally, the application must determine how long to wait before discarding a transaction and retrying the packet with a new transaction number when a command has been sent but a response hasn't been received. The expected latency varies across different communication mediums but the application should be aware of this variability and set the maximum retry interval accordingly.

3.8 Understanding Table Definitions and Table Signatures

Since the CR200 stores data in tables, the datalogger and the application must understand and agree on the structure of each table in order to collect data. Table definitions contain the parameters that describe each table, record, and field in the datalogger. These parameters exist on the datalogger in a file with a “.TDF” extension. Obtain table definitions from the datalogger using the File Upload transaction requesting a file named “.TDF”.

Table definitions are used by the application to know what tables and fields exist and what data to expect from each table when collecting values from the CR200. In order to ensure the integrity of this table information, the application should calculate a signature of the parameters contained in each table within the table definitions. One signature should be calculated for each defined table and should be stored and used by the application to verify that the table has not changed when collecting data.

3.9 Getting Table Definitions from the CR200

Table definitions are retrieved from the CR200 with the File Upload transaction before attempting data collection. The file name in the transaction should be specified as “.TDF”. The datalogger recognizes this file extension and returns the appropriate response containing the table definitions. A hexadecimal example of the command looks like:

```
BD A0 01 70 04 10 01 00 04 1D 1D 00 00 43 50 55 3A 44 65 66
2E 74 64 66 00 00 00 00 00 00 00 80 27 EA BD
```

The response message from the datalogger contains the table definitions and may be broken over multiple packets. A function should be created that parses the table information from the response packet. This information should be used by the application to calculate table signatures and to interpret data records that are collected from the datalogger. If the table definitions are broken over multiple packets, the last File Upload Response packet should have a value in the FileOffset field that is smaller than the Swath field declared in the File Upload Command packet. An example response packet looks like:

```
BD A0 04 00 01 10 04 00 01 9D 1D 00 00 00 00 00 01 53 74 61
74 75 73 00 00 00 00 01 0C 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 8B 4F 53 76 65 72 73 69 6F 6E 00 00 00 00 00
00 00 00 01 00 00 00 08 00 00 00 08 00 00 00 00 8B 4F 53 44
61 74 65 00 00 00 00 00 00 00 00 01 00 00 00 0A 00 00 00 0A
00 00 00 00 8B 50 72 6F 67 4E 61 6D 65 00 00 00 00 00 00 00
00 01 00 00 00 10 00 00 00 10 00 00 00 00 95 50 72 6F 67 53
69 67 00 00 F1 67 BD
```

3.9.1 How to Get and Use Table Signatures

The table definition signature is a signature for the parameters describing a table. There must be one signature for each defined table in the File Upload

Response packet. Calculate the signature by starting with the first byte of the FieldName parameter and ending after the field list terminator for that table. A description of the signature algorithm and example C code showing the method used to calculate the signature can be found in Appendix B. Additional examples showing functions used to parse tables from table definitions and calculate signatures existing in the JAVA code found in Appendix D.

The table signature should be stored by the application and used in the Collect Data Command packet when collecting data from the CR200. The datalogger validates the table signature and ensures that the datalogger tables have not changed when an application requests data.

Please note that table definitions and table signatures are not specifically required if the table structure is known and the application uses the Get Values or Set Values transaction. These transactions only require specific table information and do not use a table signature.

3.10 Retrieving Data from the CR200

By default data are stored in ring memory on the datalogger and must be collected by an external application before the old values are overwritten by new values. One way an application retrieves this data is with the Collect Data transaction. An example packet that initiates the collection process looks like:

```
BD A0 01 70 04 10 01 00 04 09 09 00 00 05 00 03 43 15 00 00
00 3C 00 00 C7 DF BD
```

The response packet from the datalogger will contain data that must be parsed. The application uses table definition information to understand the data structure in the packet in order to extract the appropriate information from the response packet.

3.10.1 Interpreting Data Types

The data type determines how each value should be handled by the application. The Appendix includes some of the data types that might be encountered when collecting data from or sending data to a CR200.

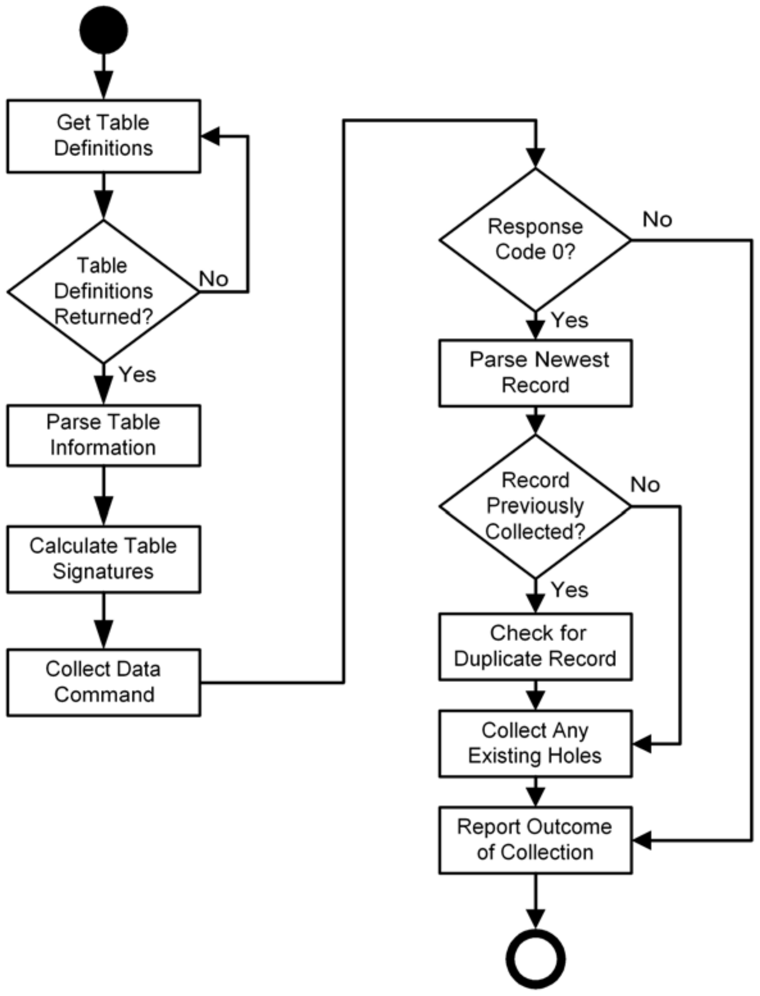
3.10.2 Data Collection Sequence

The following steps should be used when collecting data from the CR200:

1. Get the current table definitions if necessary by using the File Upload transaction.

2. If table definitions are returned, parse the table information from the response packet. This information should be saved and used to interpret collected data records. The table signature should also be calculated and used when requesting data from the datalogger.

3. Use the Collect Data Transaction to initiate data collection from the CR200 and parse the data contained in the Collect Data Response packet.


Get Table Definitions
Table Definitions Returned?
No
Yes
Parse Table Information
Calculate Table Signatures
Collect Data Command
Response Code 0?
No
Yes
Parse Newest Record
Record Previously Collected?
No
Yes
Check for Duplicate Record
Collect Any Existing Holes
Report Outcome of Collection

3.10.3 Collecting Tables and Specific Records

Within the Collect Data Command message there are many options for data collection. The CollectMode parameter of this packet describes what records will be collected from the defined tables. Some collect mode options include:

- CollectMode 0x03: Collect from the oldest record to the newest record starting with the oldest data in each table. This method of collection would be used to collect entire data tables.
- CollectMode 0x04: Collect from a defined record to the newest record in the tables defined. If the defined starting record doesn’t exist in the datalogger, data collection will start from the oldest record in the table.
- CollectMode 0x05: Collect the most recent records, where the number of records to collect is a definable parameter.
- CollectMode 0x06: Collect from a defined record up to but not including a second defined record. This method of collection would be useful to collect a specific subset of records from the datalogger.

3.10.4 Getting Values from Specific Records

Use either the Collect Data Command or the Get Values transaction when attempting to collect a specific value or swath of values from an individual record. These values are referenced by the table and field name, which can be found in the table definitions collected from a station if the user does not already know them. The Collect Data Command allows multiple fields to be specified while the Get Values transaction focus on a single field at a time.

Once the table and field names are known the Collect Data or Get Values Command packet can be sent to the datalogger specifying the exact values that are wanted. The Collect Data or Get Values Response packet returns the values requested or if an error occurs, the error is specified but no values are returned.

These transactions are designed to minimize complexity, by allowing the application to dictate the data type of the values that are returned. On a Collect Data or Get Values transaction, the datalogger must convert the data value to the data type requested. If the datalogger does not support a requested data type or the conversion is not possible, the response will indicate that the data type conversion is not supported. In general, the safest data type to request is IEEE4.

3.11 Controlling Packet Size

Because of the compact size of the CR200, it has a limited buffer space for receiving packets. Therefore, an application should not send messages to the datalogger that exceed 100 bytes including the header. This maximum packet size information can be obtained from the datalogger if necessary via the Get Settings transaction. The setting containing this information is named “MaxPktSize”.

Additionally, the application must not request packets from the datalogger that exceed the 1000 byte PakBus message limit. The requested number of bytes from the CR200 datalogger should always be less than this maximum size to stay within the limits of the CR200 datalogger and the PakBus message limit.

Section 4. The CR1000 Type Datalogger

The CR1000 type datalogger (CR1000, CR3000, and CR800) is a rugged and versatile measurement device. This datalogger contains a CPU and both digital and analog inputs and outputs. The CR1000 type datalogger uses a PakBus operating system and communicates with applications via the BMP5 message protocol. Programs sent to the datalogger are written in a BASIC-like language that includes data processing and analysis routines. These programs run on a precise execution interval and will store measurements and data in tables.

4.1 Dealing with Unexpected Commands

Since communication with a CR1000 type datalogger is packet based, chances are an application will receive unexpected or asynchronous commands from the datalogger. The response packet received may or may not be related to the last command packet sent by the application or may not even be destined for the application. Transaction numbers generated by the application and included in the command message are one way to track appropriate responses. By identifying the message type and knowing the transaction number, response packets can be appropriately handled by the application. In addition, the application should ignore messages that have a DstPhyAddr value in the packet header that is different than the address being used by the application.

An application may also periodically receive packets from the datalogger that weren't requested but which need a response. For example, the datalogger may send out a Hello transaction to which the application should respond. If the application receives a command packet and does not respond, the datalogger will continue to send command packets until the application answers appropriately. If the application receives any packets from a datalogger that haven't been discussed in this documentation, the application should respond with a PakCtrl Delivery Failure Message (Packet Type 0x81) specifying that the command is not currently implemented or understood by the application.

4.2 Getting the Attention of the Datalogger and Establishing a Baud Rate

The application should initiate communication with the datalogger by using a SerPkt Link-state "Ring" transaction. The datalogger will return a SerPkt Link-state "Ready" packet to let the application know to proceed with communication. Although the Ring and Ready packets should be used, they are not required. If the PakBus address of the datalogger is known, the application can send any appropriate message to the datalogger at anytime.

The following is an example "Ring" packet from an application with a PakBus address of 4094 sent to a datalogger with a PakBus address of 1 to determine the communication link state:

```
BD 90 01 0F FE 71 D2 BD
```

The following is a corresponding example of a "Ready" response from a datalogger with an address of 1 to an application with an address of 4094 letting the application know it can proceed with communication:

```
BD AF FE 00 01 5A 89 BD
```

The datalogger may not be aware that a connection has been established from the PC when beginning the initial communication process. The application should initiate communication to the CR1000 by sending a series of 0xbd SerSyncBytes before the initial packet to wake up the datalogger, clear the communication buffer, and determine the communication baud rate.

Since the CR1000 type datalogger supports automatic baud-rate synchronization, the recommended procedure is to send at least six SerSyncBytes before sending the Ring packet.

4.3 Getting the PakBus Address

Knowing the address of the CR1000 type datalogger is necessary for communication. Every PakBus device needs a PakBus address to send and receive packets. In addition all devices on the network need unique addresses. The valid range for PakBus addresses is 1to 4094. The address range of 1 to 3999 is normally reserved for dataloggers while the address range of 4000 to 4094 is normally reserved for applications. The CR1000 type datalogger ships with a default PakBus address of 1 but could have any address within the allowable range.

If the address of the CR1000 type datalogger is unknown, it can be obtained with a PakCtrl Hello Request Message. Since all PakBus dataloggers on the network will respond to this broadcast type message, make sure you are connected to a single datalogger before you send a PakCtrl Hello Request Message in order to determine that specific datalogger’s address.

The DstPhyAddr and DstNodeId in the header of the Hello Request Message should be specified as 4095 to indicate a broadcast packet. The datalogger will respond to the application with a Hello Command transaction that contains its PakBus address in the header.

4.4 Getting and Setting Datalogger Settings

The DevConfig protocol is used to get settings from and set setting on the CR1000 type datalogger. The DevConfig Get Settings transaction is used to request specific settings from the datalogger according to the setting ID. Similarly the setting ID is used with the DevConfig Set Settings transaction when attempting to change a particular setting on the datalogger.

In both of these cases, the setting ID used comes from the Device Description File for the CR1000 datalogger found in Appendix C. This XML file contains setting ID catalogs corresponding to specific operating system versions for the CR1000 type datalogger. Since parsing this XML file may be difficult, viewing the file and merely including the necessary settings with a corresponding ID in the application is an acceptable method for getting settings from and setting settings in a CR1000 type datalogger.

Settings are specific to the operating system of the CR1000 type datalogger. An example of some common settings for CR1000 type datalogger operating systems are taken from the Device Description File in Appendix C include but are not limited to those described in the following table. Discover additional settings for this and other operating systems by reviewing the included Device Description File in Appendix C.

Setting ID	Name
0	OS Version
1	Serial Number
2	Station Name
3	PakBus Address
4	Security

4.5 Getting and Setting the Clock

The CR1000 type datalogger contains a precise clock that drives the execution interval of the running program. An application can either check or set the datalogger clock with the Clock Transaction.

Before attempting to set the datalogger clock, the application should always check the current time. Then, if necessary, the appropriate adjustment can be made by either adding time to or subtracting time from the datalogger clock with the Clock Command message. A hexadecimal example of this message that is checking the clock for a datalogger with a PakBus address of 1 looks like:

```
BD A0 01 4F FE 10 01 0F FE 17 17 00 00 00 00 00 00 00 00 00
00 B2 B3 BD
```

The response from the datalogger to the clock request comes in the form of the Clock Response message. A hexadecimal example of a clock response packet looks like:

```
BD AF FE 00 01 1F FE 00 01 97 17 00 1B FA 2A 61 C8 00 00 00
04 FA BD
```

4.6 The Program Structure

CR1000 type datalogger programs are written with a programming language called CRBasic. This BASIC-like programming language facilitates the creation of datalogger programs capable of precise measurement and data analysis. Programs are sent to the CR1000 type datalogger as ASCII text where the datalogger operating system compiles and runs them.

Datalogger programs execute on a precise interval to process data or store measurements. Data are stored in tables that are defined by the datalogger program. The CR1000 type datalogger includes the Status table and the Public table by default. The number of additional tables that can be defined by the datalogger program is only limited by the amount of memory available in the datalogger.

The CR1000 type datalogger compiles the program and creates tables that are stored in battery backed RAM. Therefore, when the datalogger is powered down, the data remains. However, since the datalogger program creates the tables, all data are erased when a new datalogger program is compiled and run by the datalogger.

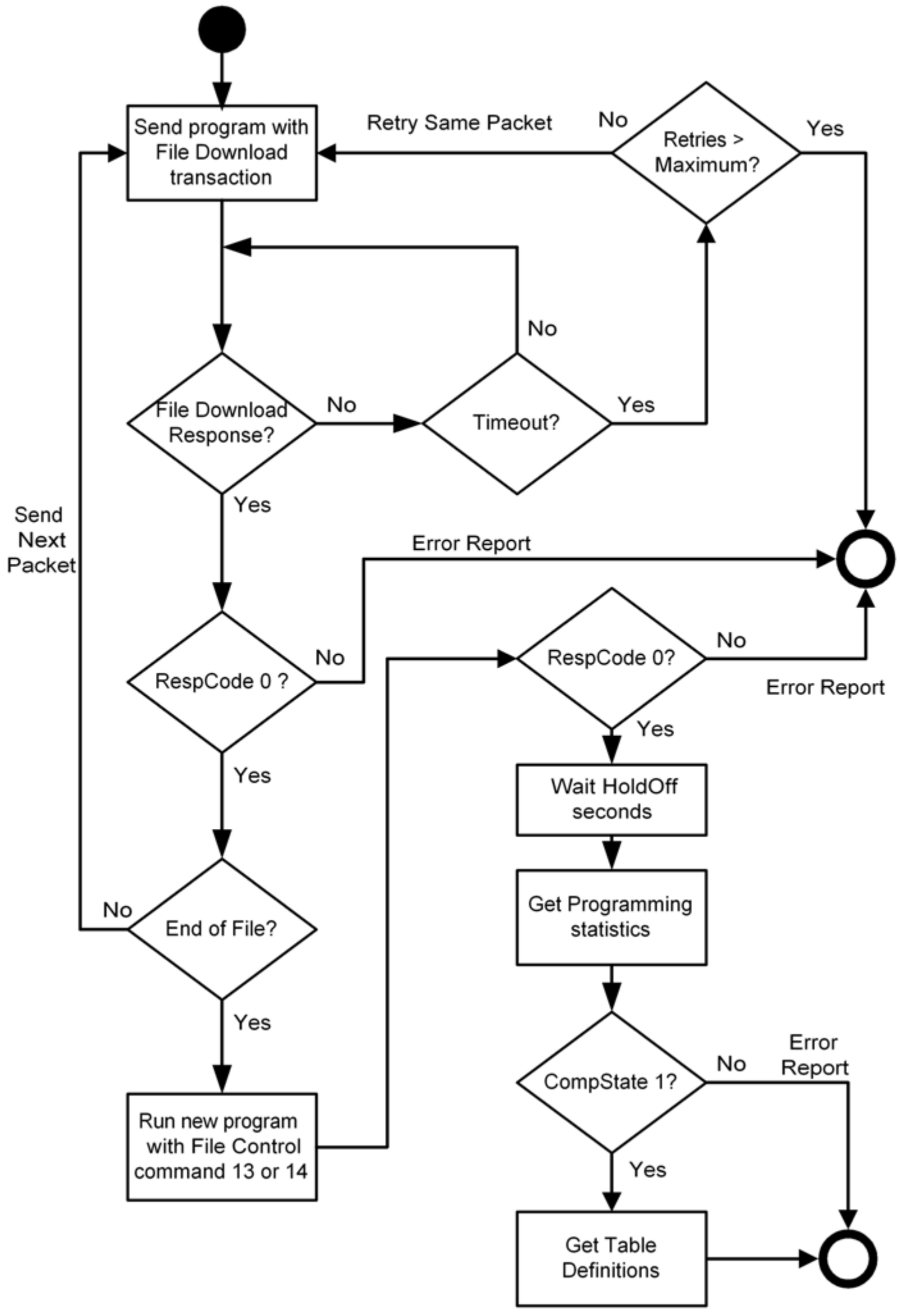
4.7 Sending a Program to the Datalogger

The CR1000 type datalogger accepts text programs written with CRBasic syntax and automatically compiles these programs before running them. As long as the program contains correct CRBasic syntax, the datalogger should compile and run the program.

Use the File Download transaction to send the program from the application to the datalogger. The file name and device memory location must be specified. Possible locations for storing files in the CR1000 type datalogger include CPU, USR, and CRD.

The CR1000 type datalogger looks at the file extension provided with the file name and attempts to compile the program appropriately. For example, a file name of "CPU:ProgName.CR1" will be compiled as a new datalogger program in datalogger memory. Possible file extensions include ".CR1", which designates a datalogger program and ".OBJ", which designates a datalogger operating system.

The complexity of sending a program to the datalogger is shown in the following diagram.



Use the File Download Command message to send the new program file to the datalogger. The new program file must have the ".CR1" file extension. If the program is larger than the MaxPktSize of the datalogger, it should be separated into packets that will fit into the MaxPktSize. After sending each packet, the application should check the RespCode and FileOffset parameters for errors. The file download operation should stop immediately if an error occurs and the error should be handled. If a response is not received, the application can retry the same packet. If there are no problems, the packets should be sent in sequential order to the datalogger.

Send a File Control Command with the FileCmd parameter set to "0x0d" or "0x0e" to specify the name of the new program, stop the old program, delete its files, and start the new program on the datalogger. Check the File Control Response. If the RespCode returns a zero, determine the amount of time to wait as declared in the HoldOff parameter and wait at lest that amount of time before continuing the process. Otherwise, report and act on the error message.

Send the Get Programming Statistics transaction and obtain compile results to verify the new datalogger program information. Since the datalogger is compiling the program and allocating table space, the application may need to wait for this response. The datalogger will send a Please Wait message if a delay is going to occur.

Once the application verifies that the datalogger has properly compiled and is running the new program, table definitions can be retrieved and used by the application.

4.7.1 Interpreting the Response

After the datalogger program has been sent to the CR1000 type datalogger, the application should anticipate a File Download Response message. The response code within this message indicates the next action the application should attempt. Possible response codes include: complete (0x00), permission denied (0x01), insufficient resources or memory full (0x02), invalid fragment number (0x09), invalid file name (0x0d), and file is not currently accessible (0x0e).

4.7.2 Handling Rejection

When everything goes as planned, the datalogger indicates the program was sent successfully with a response code of “complete”. However, if a problem occurs when sending a program, the datalogger will indicate the nature of the problem with a different response code.

For example, a “permission denied” message indicates that security is enabled on the CR1000 type datalogger and an improper security code has been sent to the datalogger. The application should prompt for and send the correct security code. Additionally, the CR1000 type datalogger can store multiple programs and files so an “insufficient resources or memory full” response code requires the application to use the File Control transaction to remove existing programs or files and make room for the new program.

Finally, the application must determine how long to wait before discarding a transaction and retrying the packet with a new transaction number when a command has been sent but a response hasn’t been received. The expected latency varies across different communication mediums but the application should be aware of this variability and set the maximum retry interval accordingly.

4.7.3 Erasing Files on the CFM100

The CompactFlash™ Module of the CR1000 and CR3000 provides additional storage for data, programs, and files. The File Control transaction can administer and delete files from the CFM100 in the same manner as deleting files from datalogger memory but by specifying a file and location on the memory card instead of a file and location in the datalogger memory.

4.7.4 Deleting Program Files

When loading a new datalogger program to the CR1000 type datalogger, the old datalogger program can remain in datalogger memory for future use or reference. Although data tables are recreated and the data for the currently running program will be lost when a new program begins running on the datalogger, the old program does not have to be deleted. However, if the datalogger memory becomes too full or if the old program is no longer needed the File Control transaction provides a method of deleting files either when sending a new program to the datalogger or as an independent transaction. The FileCmd codes in the File Control transaction include the following options:

- 0x01: Compile and run the new program
- 0x02: Toggle the “run on power-up” option on the datalogger program specified
- 0x03: Make the specified file hidden so it cannot be downloaded or viewed.
- 0x04: Delete the specified file
- 0x05: Format the datalogger
- 0x06: Compile and run the program without deleting data tables
- 0x07: Stop the running program
- 0x08: Stop the running program and delete all associated files
- 0x09: Make the specified file the new operating system
- 0x0a: Compile and run the program without changing the “run on power-up” file
- 0x0b: Pause execution of the running program
- 0x0c: Resume execution of the running program
- 0x0d: Stop the running program, delete associated files, and run the specified program while marking it as the “run on power-up” program
- 0x0e: Stop the running program, delete associated files, and run the specified program without changing the “run on power-up” attribute

The CR1000 type datalogger can store files in memory for future use or retrieval. If the files contained on the CR1000 type datalogger are not known, obtain a list of the files by requesting a file named “.DIR” with the File Upload transaction. Once the list of files has been retrieved, use the File Control transaction to make necessary changes to the files or file attributes.

4.8 Understanding Table Definitions and Table Signatures

Since the CR1000 type dataloggers store data in tables, the datalogger and the application must understand and agree on the structure of each table in order to collect data. Table definitions contain the parameters that describe each table, record, and field in the datalogger and are contained in a file on the datalogger with a “.TDF” extension. This file is obtained from the datalogger using the File Upload transaction.

Table definitions are used by the application to know what tables and fields exist and what data to expect from each table when collecting values from the CR1000 type datalogger. In order to ensure the integrity of this table information, the application should calculate signatures for the tables within the table definitions. One signature should be calculated for each defined table and should be stored and used by the application to verify that the table has not changed when collecting data.

4.9 Getting Table Definitions

Table definitions are retrieved from the CR1000 type datalogger with the File Upload transaction. The file name in the transaction should be specified as ".TDF". The datalogger will recognize this file extension and return the appropriate response containing the table definitions. A hexadecimal example of the command packet looks like:

```
BD A0 01 70 04 10 01 00 04 1D 1D 00 00 43 50 55 3A 44 65 66
2E 74 64 66 00 00 00 00 00 00 00 80 27 EA BD
```

The response message from the datalogger will contain the table definitions and may be broken over multiple packets. A function should be created to parse the table information from the response packet. This information should be saved by the application and used to calculate table signatures and to interpret data records that are collected from the datalogger. If the table definitions are broken over multiple packets, the last File Upload Response packet should have a value in the FileOffset field that is smaller than the Swath field declared in the File Upload Command packet. An example response packet looks like:

```
BD A0 04 00 01 10 04 00 01 9D 1D 00 00 00 00 00 01 53 74 61
74 75 73 00 00 00 00 01 0C 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 8B 4F 53 76 65 72 73 69 6F 6E 00 00 00 00 00
00 00 00 01 00 00 00 08 00 00 00 08 00 00 00 00 8B 4F 53 44
61 74 65 00 00 00 00 00 00 00 00 01 00 00 00 0A 00 00 00 0A
00 00 00 00 8B 50 72 6F 67 4E 61 6D 65 00 00 00 00 00 00 00
00 01 00 00 00 10 00 00 00 10 00 00 00 00 95 50 72 6F 67 53
69 67 00 00 F1 67 BD
```

4.9.1 How to Get and Use Table Signatures

The table definition signature is a signature on the parameters describing a table. There must be one signature for each defined table in the File Upload Response packet. Calculate the signature by starting with the first byte of the FieldName parameter and ending after the field list terminator for that table. A description of the signature algorithm and example C code showing the method used to calculate the signature can be found in Appendix B. Additional examples showing functions used to parse tables from table definitions and calculate signatures existing in the JAVA code found in Appendix D.

The table signature should be stored by the application and used in the Collect Data Command packet when collecting data from the CR1000 type datalogger. The datalogger validates the table signature to ensure that the datalogger tables have not changed when an application requests data.

4.10 Retrieving Data

By default data are stored in ring memory on the datalogger and must be collected by an external application before the old values are overwritten by new values. The data are stored in tables in the CR1000 type datalogger and an application retrieves this data using the Collect Data transaction. An example of a packet that initiates the collection process looks like:

```
BD A0 01 70 04 10 01 00 04 09 09 00 00 05 00 03 43 15 00 00
00 3C 00 00 C7 DF BD
```

The response packet from the datalogger will contain data that must be parsed. The application uses table definition information to understand the data structure in the packet in order to extract the appropriate information from the response packet.

4.10.1 Interpreting Data Types

The data type determines how each value should be handled by the application. The Appendix includes a table for some of the data types that might be encountered when collecting data from or sending data to a CR1000 type datalogger.

4.10.2 Data Collection Sequence

The following steps should be used when collecting data from the CR1000 type datalogger:

Get the current table definitions if necessary by using the File Upload transaction.

When table definitions are returned, parse the table information from the response packet. This information should be saved and used when collecting data records. Each table signature should be calculated, saved, and then used when requesting data from the datalogger.

Use the Collect Data Transaction to initiate data collection from the CR1000 type datalogger and parse the data contained in the Collect Data Response packet.

4.10.3 Collecting Tables and Specific Records

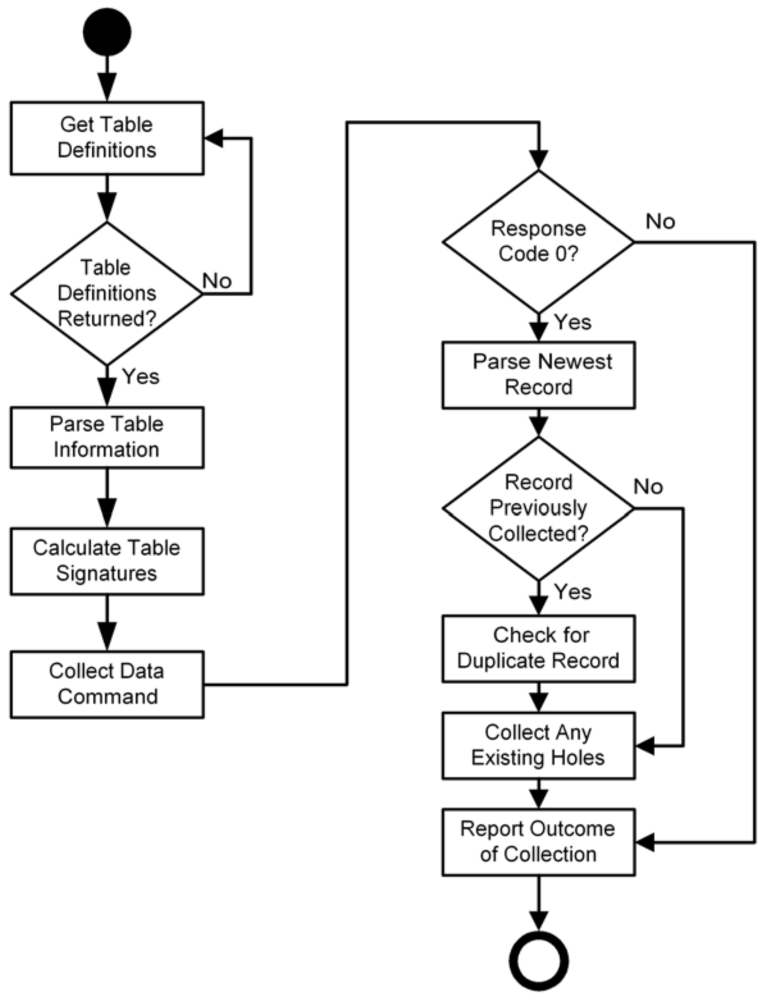
Within the Collect Data Command message there are many options for data collection. The CollectMode parameter of this packet describes what records will be collected from the defined tables. Some collect mode options include:

- CollectMode 0x03: Collect from the oldest record to the newest record starting with the oldest data in each table. This method of collection would be used to collect entire data tables.

- CollectMode 0x04: Collect from a defined record to the newest record in the tables defined. If the defined starting record doesn’t exist in the datalogger, data collection will start from the oldest record in the table.

- CollectMode 0x05: Collect the most recent records, where the number of records to collect is a definable parameter.

- CollectMode 0x06: Collect from a defined record up to but not including a second defined record. This method of collection would be useful to collect a specific subset of records from the datalogger.


Get Table Definitions
Table Definitions Returned?
No
Yes
Parse Table Information
Calculate Table Signatures
Collect Data Command
Response Code 0?
No
Yes
Parse Newest Record
Record Previously Collected?
No
Yes
Check for Duplicate Record
Collect Any Existing Holes
Report Outcome of Collection

4.10.4 Getting Values from Specific records

Use either the Collect Data Command or the Get Values transaction when attempting to collect a specific value or swath of values from an individual record. These values are referenced by the table and field name, which can be found in the table definitions collected from a station if the user does not already know them. The Collect Data Command allows multiple fields to be specified while the Get Values transaction focus on a single field at a time.

Once the table and field names are known the Collect Data or Get Values Command packet can be sent to the datalogger specifying the exact values that are wanted. The Collect Data or Get Values Response packet returns the values requested or if an error occurs, the error is specified but no values are returned.

These transactions are designed to minimize complexity, by allowing the application to dictate the data type of the values that are returned. On a Collect Data or Get Values transaction, the datalogger must convert the data value to the data type requested. If the datalogger does not support a requested data type or the conversion is not possible, the response will indicate that the data type conversion is not supported. In general, the safest data type to request is IEEE4.

4.11 Collecting Files from the Datalogger

The CR1000 type datalogger can store files in memory for future use or retrieval. The list of files contained in datalogger memory can be obtained by requesting a file name of ".DIR" with the File Upload transaction. The datalogger responds with a list of files that are stored on the datalogger. After obtaining the directory listing of files that exist on the datalogger, use the File Upload transaction to retrieve a specific file from the datalogger.

4.12 Controlling Packet Size

In order to stay within the maximum allowed packet size for the PakBus protocol, an application must not request packets from the datalogger that exceed the 1000 byte message size limit. The requested number of bytes from the datalogger should always be less than this maximum size including the header information in order to stay within the limits of the datalogger and PakBus message limit.

Appendix A. Data Types Summary

Name	Code	Size	Description
Byte	1	1	One-byte unsigned integer
UInt2	2	2	Two-byte unsigned integer (MSB first)
UInt4	3	4	Four-byte unsigned integer (MSB first)
Int1	4	1	One-byte signed integer
Int2	5	2	Two-byte signed Integer (MSB first)
In4	6	4	Four-byte signed Integer (MSB first)
FP2	7	2	Two-byte final storage floating point
FP3	15	3	Three-byte final storage floating point
FP4	8	4	Four-byte final storage floating point (CSI Format)
IEEE4B	9	4	Four-byte floating point (IEEE standard, MSB first)
IEEE8B	18	8	Eight-byte floating point(IEEE standard, MSB first)
Bool8	17	1	Byte of flags
Bool	10	1	Boolean value
Bool2	27	2	Boolean value
Bool4	28	4	Boolean value
Sec	12	4	Four-byte integer used for one second resolution time (MSB First)
USec	13	6	Six-byte unsigned integer, 10’s of milliseconds resolution (MSB first)
NSec	14	8	Two four-byte integers, nanosecond time resolution (MSB first)
ASCII	11	n	A fixed length string formed by using an array of ASCII characters. The unused portion of the fixed length should be padded with NULL characters or spaces.
ASCIIZ	16	n + 1	A variable length string formed by an array of ASCII characters and terminated with a NULL character.
Short	19	2	Two-byte integer (LSB first)
Long	20	4	Four-byte integer (LSB first)
UShort	21	2	Two-byte unsigned integer (LSB first)
ULong	22	4	Four-byte unsigned integer (LSB first)
IEEE4L	24	4	Four-byte floating point (IEEE format, LSB first)
IEEE8L	25	8	Eight-byte floating point (IEEE format, LSB first)
SecNano	23	8	Two Longs (LSB first), seconds, then nanoseconds

Appendix B. Calculating Packet Signatures and the Signature Nullifier

The CSI signature algorithm, when applied to a block of data, produces a unique value that is a function of the specific sequence and number of bytes under consideration. It is a simple algorithm used in a similar manner as a Cyclic-Redundancy-Check (CRC). We use the signature algorithm instead of the CRC primarily for historic reasons.

The following block of code is an example implementation of the signature algorithm in C. To generate the signature of a block of bytes, initialize the “seed” to 0xaaaa then pass the pointer to the first byte of the block, specifying “swath” as the number of bytes in the block. The returned value is the signature of the block.

```
// signature algorithm.
// Standard signature is initialized with a seed of
// 0xaaaa. Returns signature.  If the function is called
// on a partial data set, the return value should be
// used as the seed for the remainder

typedef unsigned short uint2;
typedef unsigned long uint4;
typedef unsigned char byte;

uint2 calcSigFor(void const *buff, uint4 len, uint2 seed=0xAAAA)
{
  uint2 j, n;
  uint2 rtn = seed;
  byte const *str = (byte const *)buff;

  // calculate a representative number for the byte
  // block using the CSI signature algorithm.
  for (n = 0; n < len; n++)
  {
    j = rtn;
    rtn = (rtn << 1) & (uint2)0x01FF;
    if (rtn >= 0x100)
    rtn++;
    rtn = (((rtn + (j >> 8) + str[n]) & (uint2)0xFF) | (j << 8));
  }
  return rtn;
} // calcSigFor
```

In the link level frame, a value called a signature nullifier is used. To calculate the signature nullifier, first calculate the next “seed”. The next seed is the value of the signature without the next byte of the sequence added in. The following code fragment shows the generation of a signature nullifier:

```
uint2 calcSigNullifier(uint2 sig)
{
  // calculate the value for the most significant
  // byte then run this value through the signature
  // algorithm using the specified signature as seed.
  // The calculation is designed to cause the least
  // significant byte in the signature to become zero.
  uint2 new_seed = (sig << 1)&0x1FF;
  byte null1;
  uint2 new_sig = sig;

  if(new_seed >= 0x0100)
    new_seed++;
  null1 = (byte)(0x0100 - (new_seed + (sig >> 8)));
  new_sig = calcSigFor(&null1,1,sig);

  // now perform the same calculation for the most significant byte
  // in the signature. This time we will use the signature that was
  // calculated using the first null byte

  byte null2;

  new_seed = (new_sig << 1)&0x01FF;
  if(new_seed >= 0x0100)
    new_seed++;
  null2 = (byte)(0x0100 - (new_seed + (new_sig >> 8)));

  // now form the return value placing null in the most
  // significant byte location
  uint2 rtn = null1;
  rtn <<= 8;
  rtn += null2;
  return rtn;
}// calcSigNullifier
```

Appendix C. Device Description Files

Applications that need to deal with device settings must reference a library of device description XML files. These files are identified with a ".dd" extension and are subject to change with new versions of the CR1000 type datalogger operating systems. Each file includes the following information about a device:

1. The device's device type code

2. The common model number for that device

3. Information about the protocol used to configure the device

4. A setting catalog for each major version of the device. The setting catalog will describe the details of all settings that are supported by the device.

Find the specific device setting ID in the Device Description File. That ID can be used within an application to get or setting datalogger settings. Some of the CR1000 type datalogger device setting IDs with their accompanying names and descriptions can be found in the CR1000 partial Device Description File below:

CR1000.dd

```
<?xml version="1.0"?>
<!DOCTYPE device-description SYSTEM "device-description.dtd">

<device-description
  device-type="12"
  model-no="CR1000"
  config-protocol="pakbus">

  <!-- This catalog describes the settings for OS version CR1000.04 and newer-
-->
  <setting-catalog major-version="5">

    <setting id="0" name="OS Version" read-only="true">
      <string name="OS Version" length="20">
        <description>Specifies the version of the operating system
        currently in the datalogger.</description>
      </string>
    </setting>

    <setting id="1" name="Serial Number" read-only="true">
      <uint4 name="Serial Number">
        <description>Specifies the datalogger serial number assigned
        by the factory when the datalogger was calibrated.</description>
      </uint4>
    </setting>
```

```
<setting id="2" name="Station Name">
  <string name="Station Name" length="64">
    <description>Specifies a name assigned to this station.</description>
  </string>
</setting>

<setting id="3" name="PakBus Address">
  <uint2 name="PakBus Address" min="1" max="4094">
    <description>Specifies the PakBus address of the CR1000.</description>
  </uint2>
</setting>

<setting id="4" name="Security">
  <uint2 name="Security Level 1">
     <description>Specifies Level 1 Security.</description>
     </uint2>
  <uint2 name="Security Level 2">
     <description>Specifies Level 2 Security.</description>
     </uint2>
  <uint2 name="Security Level 3">
     <description>Specifies Level 3 Security.</description>
     </uint2>
  </setting>

<setting id="5" name="Is Router">
  <bool name="Is Router">
  </bool>
</setting>

<setting id="6" name="PakBus Nodes Allocation">
  <uint2 name="PakBus Nodes Allocation" min="2" max="4094">
    <description>Specifies the amount of memory that the CR1000
    allocates for maintaining PakBus routing information.  This
    value represents roughly the maximum number of PakBus nodes
    that the CR1000 will be able to track in its routing
    tables.</description>
  </uint2>
</setting>

<setting id="7" name="Baud Rate RS232">
  <enumi4 name="Baud Rate RS232">
  </enumi4>
</setting>

<setting id="8" name="Baud Rate ME">
  <enumi4 name="Baud Rate ME">
  </enumi4>
</setting>

<setting id="9" name="Baud Rate COM310">
  <enumi4 name="Baud Rate COM310">
  </enumi4>
</setting>
```

```
<setting id="10" name="Baud Rate SDC7">
      <enumi4 name="Baud Rate SDC7">
      </enumi4>
    </setting>


    <setting id="11" name="Baud Rate SDC8">
      <enumi4 name="Baud Rate SDC8">
      </enumi4>
    </setting>

    <setting id="12" name="Baud Rate COM1">
      <enumi4 name="Baud Rate COM1">
      </enumi4>
    </setting>

    <setting id="13" name="Baud Rate COM2">
      <enumi4 name="Baud Rate COM2">
      </enumi4>
    </setting>

    <setting id="14" name="Baud Rate COM3">
      <enumi4 name="Baud Rate COM3">
      </enumi4>
    </setting>

    <setting id="15" name="Baud Rate COM4">
      <enumi4 name="Baud Rate COM4">
      </enumi4>
    </setting>

    <setting id="17" name="Beacon Interval RS232">
      <uint2 name="Beacon Interval RS232">
      </uint2>
    </setting>

    <setting id="18" name="Beacon Interval ME">
      <uint2 name="Beacon Interval ME">
      </uint2>
    </setting>

    <setting id="20" name="Beacon Interval SDC7">
      <uint2 name="Beacon Interval SDC7">
      </uint2>
    </setting>

    <setting id="21" name="Beacon Interval SDC8">
      <uint2 name="Beacon Interval SDC8">
      </uint2>
    </setting>

    <setting id="22" name="Beacon Interval COM1">
      <uint2 name="Beacon Interval COM1">
      </uint2>
    </setting>
```

```
<setting id="23" name="Beacon Interval COM2">
  <uint2 name="Beacon Interval COM2">
  </uint2>
</setting>

<setting id="24" name="Beacon Interval COM3">
  <uint2 name="Beacon Interval COM3">
  </uint2>
</setting>

<setting id="25" name="Beacon Interval COM4">
  <uint2 name="Beacon Interval COM4">
  </uint2>
</setting>

<setting id="26" name="Beacon Interval ETHERNET">
  <uint2 name="Beacon Interval ETHERNET">
  </uint2>
</setting>

<setting id="27" name="Verify Interval RS232">
  <uint2 name="Verify Interval RS232">
  </uint2>
</setting>

<setting id="28" name="Verify Interval ME">
  <uint2 name="Verify Interval ME">
  </uint2>
</setting>

<setting id="29" name="Verify Interval COM310">
  <uint2 name="Verify Interval COM310">
  </uint2>
</setting>

<setting id="30" name="Verify Interval SDC7">
  <uint2 name="Verify Interval SDC7">
  </uint2>
</setting>

<setting id="31" name="Verify Interval SDC8">
  <uint2 name="Verify Interval SDC8">
  </uint2>
</setting>

<setting id="32" name="Verify Interval COM1">
  <uint2 name="Verify Interval COM1">
  </uint2>
</setting>

<setting id="33" name="Verify Interval COM2">
  <uint2 name="Verify Interval COM2">
  </uint2>
</setting>
```

```
<setting id="34" name="Verify Interval COM3">
      <uint2 name="Verify Interval COM3">
      </uint2>
    </setting>

    <setting id="35" name="Verify Interval COM4">
      <uint2 name="Verify Interval COM4">
      </uint2>
    </setting>

    <setting id="36" name="Verify Interval ETHERNET">
      <uint2 name="Verify Interval ETHERNET">
      </uint2>
    </setting>

    <setting id="49" name="Max Packet Size">
      <uint2 name="Max Packet Size" min="16" max="1000">
        <description>Specifies the maximum number of bytes per data collection
packet.</description>
      </uint2>
    </setting>

<setting id="50" name="USR: Drive Size">
      <uint4 name="USR:Drive Size" min="0" max="4000000">
        <description>Specifies the size in bytes allocated for the “USR:” ram disk
drive.</description>
      </uint2>
    </setting>

    <setting id="51" name="Files Manager" repeat-count="4">
      <uint2 name="Files Manager" format-prefix="(" format-postfix=",">
      </uint2>
      <string name="Name Prefix" length="64" format-postfix=",">
      </string>
      <uint4 name="Number of Files" format-postfix=")">
      </uint4>
    </setting>

    <setting id="52" name="IP Address">
      <string name="IP Address" length="20">
      </string>
    </setting>

    <setting id="53" name="IP Gateway">
      <string name="IP Gateway" length="20">
      </string>
    </setting>

    <setting id="54" name="IP Mask">
      <string name="IP Mask" length="20">
      </string>
    </setting>
    <setting id="55" name="IP Port">
      <uint2 name="IP Port">
      </uint2>
    </setting>

  </setting-catalog>
</device-description>
```

Appendix D. JAVA Example Code

```
import java.io.*;
import java.util.*;
import java.net.*;

/**
* A simple PakBus command line application
 * that demonstrates how to communicate with a CR200 datalogger
 *
 * @author Campbell Scientific, Inc.
 * @version 1.0 Preliminary
 */
class PBExample{
   public static final long nsecPerSec = 1000000000L;
   public static final long nsecPerMSec = 1000000L;
   public static final long msecPerSec = 1000L;

   public static Socket socket;

   /**
    * Reads the input from datalogger
    */
   public static BufferedInputStream in_stream;

   /**
    * Stores the packet once read in off the stream
    */
   public static Packet in_packet;

   /**
    * Writes the output to the datalogger
    */
   public static DataOutputStream out_stream;

   /**
    * Buffer for the outgoing packet
    */
   public static Packet out_packet;

   public static int GetCommandStatus;
   public static String NameList;
   public static int file_offset;
   public static int tabledefloop;
   public static int sendseconds;
   public static GregorianCalendar DLtime; //Store the last Datalogger time
   public static GregorianCalendar PCtime; //Store the last PC time
   public static short setclockcnt;
   public static String Model;
   public static String Version;
   public static String TableDefStr;
   public static short dest_address = 4095; // start with broadcast address
   public static short source_address = 4092;
```

```
/**
 * Application main
 */
public static void main(String[] args) {
   try {
      socket = new Socket("63.255.173.242", 23);
      socket.setTcpNoDelay(true);

    //The input streams and output streams are used through out
    //this example for handling
    //communication to/from the datalogger.  In this
    //example we are getting these streams
    //from a socket, but the same streams can be initialized
    //to talk over serial IO as well.
    //The serial IO packages weren't included with the default
    //JDK so we are using sockets here.
      in_stream = new BufferedInputStream(new
      DataInputStream(socket.getInputStream()));
      out_stream = new DataOutputStream(socket.getOutputStream());
   } catch( IOException e ) {
      System.err.println( "SockConnection(), " + e );
      if( socket != null ) {
         try { socket.close(); }
         catch( IOException ee ) {}
      }
      return;
   }

   SetupDL();
   startscreen();
   InputStreamReader stdin = new InputStreamReader(System.in);
   boolean shouldExit = false;
   try
   {
      while(!shouldExit)
      {
         if(in_stream.available() > 0)
         {
            in_packet = null;
            GetLine(); // wait for a complete line
            if(in_packet != null)
            {
               switch(((int)in_packet.message_type) & 0xFF)
               {
               case (0x97) :
                  System.out.println("Received clock check response");
                  ParseClk();       // Response for clock command body
                  SetClkCnts();
                  break;

               case (0x89) :   //  Response for Collect Data Transaction
                  System.out.println("Response for Collect Data Transaction");
                  ParseDataCollectResp();
                  break;

               case (0x87):        // Response for Command format;
                  System.out.println("Response for Command format");
                  ParseCommand();
                  break;

               case 0x9a:
                  ParsePublicTbl();
                  break;
               case (0x9d) :       // Response for Upload Command
                  System.out.println("Response for Upload Command");
                  ParseTblDefs();
                  break;
               }
            }
         }
         else if(stdin.ready())
         {
            switch(stdin.read())
            {
            case '1':
               file_offset = 0;
               tabledefloop = 0;
               TableDefStr = new String();
               System.out.println("Getting Table def ");
               GetTableDef();
               break;

            case '2':
               GetPublicValue();
               SendPb();
               break;

            case '3':
               NameList = "\0";
               GetCommand();
               SendPb();
               break;

            case '4':
               setclockcnt = 0;
               sendseconds = 0;
               GetClock();
               SendPb();
               break;

            case '5':
               setclockcnt = 1;
               sendseconds = 0;
               SetClock();
               break;

            case '6':
               GetTable("Public",1);
               SendPb();
               break;

            case '7':
               System.out.println("Getting PakBusAddress");
               dest_address = 4095;
               NameList = "PakBusAddress\0";
               GetCommand();
               SendPb();
               break;
```

```
            case '8':
               System.out.println("Getting 24 hour data");
               GetTable("Data1",24);
               SendPb();
               break;

            case '9':
               NameList = "Model\0";
               GetCommand();
               SendPb();
               break;

            case 'h':
               startscreen();
               break;

            case 'x':
               shouldExit = true;
               break;

            default:
               break;
            }
         }
      }
   }
   catch ( IOException e ) {
      System.err.println(e);
   }

   System.out.println("System Shutting Down");
   try {
      stdin.close();
   }
   catch( IOException e ){
      System.err.println(e);
   }
}


/**
 * Internal - Used to display the console menu.
 */
public static void startscreen()
{
   System.out.println(" Press 1 for GetTblDef");
   System.out.println(" Press 2 for GetPublicValue");
   System.out.println(" Press 3 for GetCommand");
   System.out.println(" Press 4 for GetClock");
   System.out.println(" Press 5 for SetClock");
   System.out.println(" Press 6 for GetPublicTable");
   System.out.println(" Press 7 for GetPakBusAddress");
   System.out.println(" Press 8 for Get 24 Hour Data");
   System.out.println(" Press 9 for GetModel");
   System.out.println(" Press h to reprint this menu");
   System.out.println(" Press x to exit");
}
```

```
   //SetupDl gets the PakBusAddress by using the GetCommand procedure
   public static void SetupDL()
   {
      GetCommandStatus = 0;
      NameList = "\0";
      GetCommand();
      SendPb();
   }

   /**
    * GetLoggerAddress will broadcast the network to get a response
    * from the DL to get the pakbus address.  This will not work for
    * multiple DL's they will all respond
    */
   public static void GetCommand()
   {
      CreateHeader();
      out_packet.hi_protocol_code = Packet.protocol_pakctrl;
      out_packet.message_type = 0x07;
      out_packet.tran_no = 0x07;
      out_packet.add_string(NameList);
   }

   /**
    * Creates the PakBus header
    */
   public static void CreateHeader()
   {
      out_packet = new Packet();
      out_packet.src_address = source_address;
      out_packet.dest_address = dest_address;
   }

   /**
    * calculates the signature for a buffer
    */
   static char calcSigFor(byte[] buff, int len, char seed)
   {
      int j, n;
      char rtn = seed;
      // calculate a representative number for the byte block using the CSI
      // signature algorithm.
      for(n = 0; n < len; n++)
      {
         if(n == 0 && buff[0] == 0xBD && len > 1) //Ignore first 0xBD
            n = 1;
         j = rtn;
         rtn = (char)((rtn << 1) & (char)0x01FF);
         if(rtn >= (int)0x100)
            rtn++;
         rtn = (char)(((rtn + (j >> 8) + buff[n]) & (char)0xFF) | (j <<
8));
      }
      return rtn;
   } // calcSigFor
```

```
/**
 * Calculates the signature for a byte.
 */
static char calcSigForByte(byte buff, char seed)
{
   char rtn = (char)seed;
   char j = rtn;
   rtn = (char)((rtn << 1) & (char)0x01FF);
   if(rtn >= (int)0x100)
      rtn++;
   rtn = (char)(((rtn + (j >> 8) + buff) & (char)0xFF) | (j << 8));
   return rtn;
} // calcSigForByte

/**
 * calculates the signature nullifier
 */
static char calcSigNullifier(char sig)
{
    //calculate the value for the most significant byte. Then run this
    //value through the signature algorithm using the specified
    //signature as seed. The calculation is designed to cause the
    //least significant byte in the signature to become zero.
   char new_seed = (char)((sig << 1) & (char)0x1FF);
   byte[] null1 = new byte[1];
   int new_sig = sig;

   if(new_seed >= 0x0100)
      new_seed++;
   null1[0] = (byte)((char)0x0100 - (new_seed + (sig >> 8)));
   new_sig = calcSigFor(null1,1,sig);

    //now perform the same calculation for the most significant byte
    //in the signature. This time we will use the signature that was
    //calculated using the first null byte
   char null2;

   new_seed = (char)((new_sig << 1) & (char)0x01FF);
   if(new_seed >= 0x0100)
      new_seed++;
   null2 = (char)((char)0x0100 - (new_seed + (char)(new_sig >> 8)));

        //now form the return value placing null one in the most
        //significant byte location
   char rtn = (char)null1[0];
   rtn <<= 8;
   rtn += null2;
   return rtn;
} // calcSigNullifier

/**
 * Sends and quotes the pakbus packet
 */
public static void SendPb()
{
   try
   {
      byte[] frame = out_packet.to_link_state_packet();
```

```
         send_byte((byte)0xBD);       // first synch byte
         for(int i = 0; i < frame.length; ++i)
         {
            if(frame[i] == 0xBC || frame[i] == 0xBD)
            {
               send_byte((byte)0xBC);
               send_byte((byte)(frame[i] + 0x20));
            }
            else
               send_byte(frame[i]);
         }
         send_byte((byte)0xBD);
         out_stream.flush();
      }
      catch(IOException e)
      {
         System.out.println("SendPb(): " + e);
      }
   }

   /**
    * GetPublicValues will create the packet to get the Public table,
    * it will use the get value command and just get a swath.
    */
   public static void GetPublicValue()
   {
      CreateHeader();
      out_packet.message_type = 0x1a;
      out_packet.tran_no = 0x1a;
      out_packet.add_short((short)0); //security code
      out_packet.add_string("Public");
      out_packet.add_byte(TableDef.type_ieee4); // type code
      out_packet.add_string("SaveSite");
      out_packet.add_short((short)16);
   }

   public static void GetTableDef()
   {
      table_defs_buffer = null;
      file_offset = 0;
      CreateTableDef();
      SendPb();
   }

   /**
    * CreateTableDef will create the packet to get the TableDef,
    * assuming that it is the first table in the DL.
    */
   public static void CreateTableDef()
   {
      CreateHeader();
      out_packet.message_type = 0x1d;
      out_packet.tran_no = 0x1d;
      out_packet.add_short((short)0); // security code
      out_packet.add_string("CPU:Def.tdf");
      out_packet.add_byte((byte)0);
      out_packet.add_int(file_offset);
      out_packet.add_short((short)128);
   }
   /**
    * GetClock will create the packet to get a clock value from
    * the DL.  Thecode that is commented out is another way of
    * doing the sigNullifier but it does not take into account
    * the quote chars.
    */
   public static void GetClock()
   {
      CreateHeader();
      out_packet.message_type = 0x17;
      out_packet.tran_no = 0x17;
      out_packet.add_short((short)0); // security code
      out_packet.add_int(sendseconds);
      out_packet.add_int(0);
   }

   /**
    * Sets the datalogger clock to the PC time
    */
   static void SetClock()
   {
      sendseconds = 0;
      GetClock();      //checks the DL clock before adjustments
                       //returns seconds in 1990
      SendPb();
   }

   static private Vector table_defs = new Vector();

   /**
    * GetTable will create the packet for getting data from
    * the specified table
    */
   public static void GetTable(String table_name, int num_records)
   {
      if(table_defs.size() == 0)
      {
         System.out.println("GetTable - need table definitions to poll");
      }
      else
      {
         //locate the table in the list of table definitions
         TableDef table = null;
         for(int i = 0;
             table == null && i < table_defs.size();
             ++i)
         {
            table = (TableDef)table_defs.elementAt(i);
            if(table.table_name.equalsIgnoreCase(table_name))
            {
               System.out.println(
                  "Found table " + table_name + " at tableno = " +
table.table_no);
               break;
            }
            else
               table = null;
         }
         if(table != null)
         {
            // form the command message to poll the table
            CreateHeader();
            out_packet.message_type = 0x09;
            out_packet.tran_no = 0x09;
            out_packet.add_short((short)0); // security code
            out_packet.add_byte((byte)5); // collect most recent records
            out_packet.add_short((short)table.table_no);
            out_packet.add_short((short)table.def_sig);
            out_packet.add_int(num_records);      // specify the number of
                                                  // records to return
            out_packet.add_short((short)0); // send all fields
         }
         else
            System.out.println("Unable to locate the table def for
\"Public\"");
      }
   }

   /**
    */
   static void GetLine()
   {
      try
      {
         byte[] read_buffer = new byte[2048];
         int read_index = 0;
         char getlinesig = 0xAAAA;
         Counter timeout = new Counter();
         byte b;
         boolean unquote_next = false;
         boolean done = false;

         while(!done && timeout.elapsed() < 10000)
         {
            if(in_stream.available() > 0)
            {
               b = (byte)read_byte();
               if(b == (byte)0xBC)
               {
                  unquote_next = true;
                  continue;
               }
               if(b != (byte)0xBD)
               {
                  if(unquote_next)
                  {
                     b -= 0x20;
                     unquote_next = false;
                  }
                  getlinesig = calcSigForByte(b,getlinesig);
                  read_buffer[read_index++] = b;
               }
               else if(read_index >= 12 && getlinesig == 0)
               {
                  try
                  {
                     in_packet = new Packet(read_buffer,read_index - 2);
                     flush_io_log("end of packet detected, size = " +
in_packet.whats_left());
                     done = true;
                  }
                  catch(Exception e)
                  {
                     flush_io_log(e.toString());
                     read_index = 0;
                     getlinesig = 0xAAAA;
                  }
               }
               else
               {
                  read_index = 0;
                  getlinesig = 0xAAAA;
               }
            }
         }
      }
      catch(IOException e)
      {
         System.out.println("GetLine(): " + e);
      }
   }

  static GregorianCalendar getTimeStamp( long stamp )
  {
    // "stamp" is in nanosecs since 1990
    // we need to convert that to a Date
    GregorianCalendar cal = new GregorianCalendar(1990,0,1,0,0,0);
    int sec = (int)(stamp / 1000000000);
    int msec = (int)((stamp % 1000000000) / 1000000);
    cal.add(Calendar.SECOND, sec);
    cal.add(Calendar.MILLISECOND,msec);
    cal.add(Calendar.MILLISECOND,-cal.get(Calendar.DST_OFFSET));
    return cal;
  }

   static void ParseClk()
   {
      try
      {
         byte logger_resp = in_packet.read_byte();
         if(logger_resp == 0)
         {
            long seconds = in_packet.read_int() * nsecPerSec;

            DLtime = getTimeStamp(seconds);
            PCtime = new GregorianCalendar();
            System.out.println("DLtime = " + DLtime.getTime());
         }
         else
            System.out.println("Clock check failed: " + logger_resp);
      }
      catch(Exception e)
      {
         System.out.println("Clock Check Failed: " + e.toString());
      }
   }
   /**
    * This procedure allows the clock to receive the clock from the logger
    * and then make the calculations for the difference of the setting time
and the
    * dl time.
    */
   static void SetClkCnts()
   {
      switch(setclockcnt)
      {
         case (1):
            sendseconds = (int)((PCtime.getTimeInMillis() -
DLtime.getTimeInMillis()) / msecPerSec);
            System.out.println("Sendseconds = " + sendseconds);
            GetClock();     //  sets clock to new time
            SendPb();
            setclockcnt = 2;
            break;

         case (2):
            sendseconds = 0;
            GetClock();     // checks time
            SendPb();
            setclockcnt = 0;
            break;
      }
   }

   static void ParseCommand()
   {
      try
      {
         StringTokenizer settings = new
StringTokenizer(in_packet.read_string(),";");

         dest_address = in_packet.src_address;
         System.out.println("PakBusAddress = " + dest_address);
         while(settings.hasMoreTokens())
         {
            StringTokenizer setting = new
StringTokenizer(settings.nextToken(),"=");
            String name = setting.nextToken();
            String value = setting.nextToken();
            if(name.equalsIgnoreCase("Model"))
            {
               Model = value;
               System.out.println("Model = " + value);
            }
            else if(name.equalsIgnoreCase("Version"))
            {
               Version = value;
               System.out.println("version = " + value);
            }
         }
      }
      catch(Exception e)
      { System.out.println("ParseCommand error: " + e.toString()); }
   }

   private static Packet table_defs_buffer;
   static void ParseTblDefs()
   {
      try
      {
         int logger_resp = in_packet.read_byte();
         if(logger_resp == 0)
         {
            int returned_offset = in_packet.read_int();
            byte[] fragment = in_packet.read_bytes(in_packet.whats_left());
            if(table_defs_buffer == null)
               table_defs_buffer = new Packet();
            table_defs_buffer.add_bytes(fragment,fragment.length);
            file_offset += fragment.length;
            if(fragment.length == 128)
            {
               System.out.println("ParseTableDefs received fragment offset
" + file_offset);
               CreateTableDef();
               SendPb();
            }
            else
            {
               // verify the FSL file version
               int fsl_version = table_defs_buffer.read_byte();

               System.out.println("ParseTableDefs received complete file");
               if(fsl_version != 1)
                  throw new Exception("Invalid final storage labels version
" + fsl_version);

               // now attempt to read each table definition
               // from the buffer
               int table_no = 1;
               table_defs.clear();
               while(table_defs_buffer.whats_left() > 0)
               {
                  TableDef table_def = new
TableDef(table_no,table_defs_buffer);
                  System.out.println(
                     "Read def for table " + table_def.table_name + ", " +
table_no);
                  table_defs.addElement(table_def);
                  ++table_no;
               }
            }
         }
         else
            System.out.println("ParseTableDefs error: " + logger_resp);
      }
      catch(Exception e)
      {
         System.out.println("Parse Table Defs Exception: " + e.toString());
      }
   }
   static void ParsePublicTbl()
   {
      try
      {
         int logger_resp = in_packet.read_byte();
         if(logger_resp == 0)
         {
            System.out.print("Values from table public: ");
            while(in_packet.whats_left() >= 4)
            {
               System.out.print(in_packet.read_float());
               if(in_packet.whats_left() >= 4)
                  System.out.print(" ");
            }
            System.out.println("");
         }
         else
            System.out.println("ParsePublicTbl logger error: " +
logger_resp);
      }
      catch(Exception e)
      { System.out.println("ParsePublicTbl error: " + e.toString()); }
   } // ParsePublicTbl


   static void ParseDataCollectResp()
   {
      try
      {
         int logger_resp = in_packet.read_byte();
         if(logger_resp == 0)
         {
            int last_record_no = 0xffffffff;
            TableDef table = null;

            while(in_packet.whats_left() > 2)
            {
               // read and search for the table number
               int table_no = in_packet.read_short();
               for(int i = 0; table == null && i < table_defs.size(); ++i)
               {
                  table = (TableDef)table_defs.elementAt(i);
                  if(table.table_no == table_no)
                     break;
                  else
                     table = null;
               }
               if(table != null)
                  last_record_no = table.print_records(in_packet);
               else
               {
                  System.out.println("ParseDataCollectResp table not
found");
                  break;
               }
            }

       // we need to look at the expect more flag in the message
       // to determine if there are more
       // records that need to be collected.
            if(in_packet.whats_left() >= 1 &&
               in_packet.read_byte() != 0 &&
               last_record_no != 0xffffffff &&
               table != null)
            {
               System.out.println("Querying for more data at record " +
last_record_no);
               CreateHeader();
               out_packet.message_type = 0x09;
               out_packet.tran_no = 0x09;
               out_packet.add_short((short)0); // security code
               out_packet.add_byte((byte)4); // collect from p1 to newest
               out_packet.add_short((short)table.table_no);
               out_packet.add_short((short)table.def_sig);
               out_packet.add_int(last_record_no + 1);
               out_packet.add_short((short)0); // send all fields
               SendPb();
            }
         }
         else
            System.out.println("ParseDataCollectResp logger error: " +
logger_resp);
      }
      catch(Exception e)
      {
         System.out.println("ParseDataCollectResp error: " + e.toString());
      }
   }

   private static byte[] io_log = new byte[16];
   private static boolean io_last_tx = true;
   private static int io_log_len = 0;

   private static void flush_io_log(String comment)
   {
      int i;

      if(io_last_tx)
         System.out.print("T ");
      else
         System.out.print("R ");
      for(i = 0; i < io_log_len; ++i)
      {
         String hex = Integer.toHexString(io_log[i] & 0x00FF);
         if(hex.length() == 1)
            System.out.print("0");
         System.out.print(hex);
         System.out.print(" ");
      }
      for(i = io_log_len; i < io_log.length; ++i)
         System.out.print("   ");
      System.out.print(" ");
      for(i = 0; i < io_log_len; ++i)
      {
         char ch = (char)io_log[i];
         if(Character.isLetterOrDigit(ch))
            System.out.print(ch);
         else
            System.out.print(".");
      }
      System.out.println("");
      if(comment.length() > 0)
         System.out.println(comment);
      io_log_len = 0;
   }
```

```
private static void log_io(byte val, boolean transmitted)
{
   if(io_last_tx != transmitted && io_log_len > 0)
      flush_io_log("");
   io_log[io_log_len++] = val;
   io_last_tx = transmitted;
   if(io_log_len == io_log.length)
      flush_io_log("");
}

private static void send_byte(byte val) throws IOException
{
   log_io(val,true);
   out_stream.write(val);
}

private static int read_byte() throws IOException
{
   int rtn = in_stream.read();
   log_io((byte)rtn,false);
   return rtn;
}

protected static class Counter {

   private static final int msecPerDay = 86400000;
   private int start;

   /** <!-- Counter() -->
    * Construct and initialize start time to the current time.
    */
   public Counter()
   {
      start = counter();
   }

   /** <!-- Counter(int) -->
    * Construct and initialize start time to the specified value.
    *
    * @param msec    initial value for counter (milliseconds)
    */
   public Counter( int msec ) { this.start = msec; }

   /** <!-- reset() -->
    * Returns elapsed milliseconds and resets start time to now.
    *
    * @return        elapsed milliseconds prior to reset
    * @see #elapsed
    */
   public int reset() {
      int now = counter();
      int elapsed = diff( now, start );
      start = now;
      return elapsed;
   }
```

```
      /** <!-- elapsed() -->
       * Returns milliseconds elapsed since start or reset.
       *
       * @return        elapsed milliseconds since start or reset
       * @see #Counter()
       * @see #reset()
       */
      public int elapsed() { return diff( counter(), start ); }

      /** <!-- setStart(int) -->
       * Set the specified value as the start time.
       *
       * @param msec    value to set as new start time
       */
      public void setStart( int msec ) { this.start = msec; }

      /** <!-- counter() -->
       * Returns the value of the one day free running counter in
       * milliseconds.  The counter is synchronized with the
       * system clock so it can be used to get milliseconds into
       * the current day.
       *
       * @return        milliseconds into the current day
       */
      public static int counter() {
         return (int)((new Date()).getTime() % msecPerDay);
      }

      /** <!-- diff() -->
       * Returns the difference between two times allowing for
       * one time laps.  If the end mark has passed into a new
       * day (value of <code>mark</code> is less than <code>start</code>)
       * then the result is adjusted by adding one day. A one day counter
       * using milliseconds is assumed.
       *
       * @param mark    end time of the interval
       * @param start   start time of the interval
       * @return        <code>mark</code> - <code>start</code>; adjusted
       *            if <code>mark</code> is in second day
       */
      private static int diff( int mark, int start ) {
         if( mark >= start ) return mark - start;
         return mark - start + msecPerDay;
      }
   } //Counter class

   /** class Packet
    *
*  Encapsulates a PakBus Packet
    */
   protected static class Packet {

      private byte[] storage;
      private int storage_len;
      private int read_index;
      public byte link_state;
      public short dest_address;
      public byte expect_more_code;
      public byte priority;
      public short src_address;
      public short hi_protocol_code;
      public byte message_type;
      public byte tran_no;

      public static final byte link_off_line = 8;
      public static final byte link_ring = 9;
      public static final byte link_ready = 10;
      public static final byte link_finished = 11;
      public static final byte link_pause = 12;

      public static final byte expect_last = 0;
      public static final byte expect_more = 1;
      public static final byte expect_neutral = 2;
      public static final byte expect_reverse = 3;

      public static final byte pri_low = 0;
      public static final byte pri_normal = 1;
      public static final byte pri_high = 2;
      public static final byte pri_extra_high = 3;

      public static final byte protocol_pakctrl = 0;
      public static final byte protocol_bmp5 = 1;

      public Packet()
      {
         link_state = link_ready;
         expect_more_code = expect_more;
         priority = pri_high;
         src_address = 0;
         dest_address = 0;
         hi_protocol_code = protocol_bmp5;
         message_type = 0;
         tran_no = 0;
         read_index = storage_len = 0;
      }

      public Packet(byte[] buff, int len) throws Exception
      {
   // the incoming packet must have at least enough bytes
   // to satisfy the header
         if(len < 12)
            throw new Exception("Invalid packet length");

   // we will assume that the buffer being passed in has already
   // been framed and dequoted.  We will further assume that it
   // has a BD at the beginning and a BD at the end along with the
   // signature nullifier.  Our internal buffer will throw the
   // framing and the header away and keep only the packet content.
         int word1 = (((int)buff[0]) << 8) | ((int)buff[1]);
         int word2 = (((int)buff[2]) << 8) | ((int)buff[3]);
         int word3 = (((int)buff[4]) << 8) | ((int)buff[5]);
         int word4 = (((int)buff[6]) << 8) | ((int)buff[7]);
         link_state = (byte)((word1 & 0xF000) >> 12);
         dest_address = (short)(word1 & 0x0FFF);
         expect_more_code = (byte)((word2 & 0xC000) >> 14);
         priority = (byte)((word2 & 0x0300) >> 12);
         src_address = (short)(word2 & 0x0FFF);
         hi_protocol_code = (byte)((word3 & 0xF000) >> 12);
```

```
 // the message type and transaction number may not be present.
 // We will set them to 0 and then look for them
   tran_no = 0;
   message_type = 0;
   storage_len = 0;
   if(len >= 9)
   {
      message_type = buff[8];
      tran_no = buff[9];
      storage = new byte[len - 10];
      for(int i = 10; i < len; ++i)
      {
         ++storage_len;
         storage[i - 10] = buff[i];
      }
   }
}

protected void reserve(int len)
{
 // we need to check to make sure that the buffer has the
 // capacity for the specified length.  If it does not, we
 // will re-allocate it so that it does.
   if(storage == null)
      storage = new byte[len];
   else if(storage.length < len)
   {
 // If we don't have enough capacity.  To prevent re-allocation
 // each time, we will double the requested amount.
      byte[] temp = new byte[len * 2];
      for(int i = 0; i < storage.length; ++i)
         temp[i] = storage[i];
      storage = temp;
   }
}

public void add_bytes(byte[] buff, int buff_len)
{
   reserve(storage_len + buff.length);
   for(int i = 0; i < buff_len; ++i)
      storage[storage_len++] = buff[i];
}

public void add_byte(Byte val)
{
   reserve(storage_len + 1);
   storage[storage_len++] = val.byteValue();
}
```

```
public void add_short(Short val)
{
   byte[] temp = new byte[2];
   temp[0] = (byte)((val & 0xFF00) >> 8);
   temp[1] = (byte)(val & 0x00FF);
   add_bytes(temp,temp.length);
}

public void add_int(Integer val)
{
   byte[] temp = new byte[4];
   temp[0] = (byte)((val & 0xFF000000) >> 24);
   temp[1] = (byte)((val & 0x00FF0000) >> 16);
   temp[2] = (byte)((val & 0x0000FF00) >> 8);
   temp[3] = (byte)(val & 0x000000FF);
   add_bytes(temp,temp.length);
}

public void add_string(String val)
{
   byte[] temp = val.getBytes();
   add_bytes(temp,temp.length);
   if(val.charAt(val.length()-1) != '\0')
      add_byte((byte)0);
}

public void add_float(Float val)
{
   add_int(Float.floatToIntBits(val.floatValue()));
}

public byte[] read_bytes(int len) throws Exception
{
   if(read_index + len > storage_len)
      throw new Exception("Attempt to read past end");
   byte[] rtn = new byte[len];
   for(int i = 0; i < len; ++i)
      rtn[i] = storage[read_index++];
   return rtn;
}

public byte read_byte() throws Exception
{
   byte[] temp = read_bytes(1);
   return temp[0];
}

public short read_short() throws Exception
{
   byte[] temp = read_bytes(2);
   short rtn = (short)(
      ((short)temp[0] & 0xff) << 8 |
      ((short)temp[1] & 0xff));
   return rtn;
}
```

```
      public int read_int() throws Exception
      {
         byte[] temp = read_bytes(4);
         int rtn = (((int)temp[0] & 0xff) << 24) |
            (((int)temp[1] & 0xff) << 16) |
            (((int)temp[2] & 0xff) << 8) |
            ((int)temp[3] & 0xff);
         return rtn;
      }

      public float read_float() throws Exception
      {
         int int_val = read_int();
         return Float.intBitsToFloat(int_val);
      }

      public String read_string()
      {
         String rtn = new String();
         while(storage[read_index] != 0 && read_index < storage_len)
            rtn += (char)storage[read_index++];
         if(read_index < storage_len && storage[read_index] == 0)
            ++read_index;       // increment past the terminator
         return rtn;
      }

      public void move_past(int len)
      {
         if(read_index + len >= storage_len)
            read_index = storage_len;
         else
            read_index += len;
      }

      public void reset()
      { read_index = 0; }

      public int whats_left()
      { return storage_len - read_index; }

      public void clear()
      { storage_len = read_index = 0; }

      public int get_read_index()
      { return read_index; }

      public byte[] get_fragment(int start_pos, int end_pos) throws
Exception
      {
         if(start_pos > end_pos ||
            start_pos >= storage_len ||
            end_pos >= storage_len ||
            start_pos < 0 ||
            end_pos < 0)
            throw new Exception("invalid fragment position pointers");
         byte[] rtn = new byte[end_pos - start_pos + 1];
         for(int i = start_pos; i < end_pos; ++i)
            rtn[i - start_pos] = storage[i];
         return rtn;
      }
      public byte[] to_link_state_packet()
      {
         // form the packet header + body (less the framing characters)
         byte[] rtn = new byte[storage_len + 12];
         int i;

         rtn[0] = (byte)((link_state << 4) | (byte)((dest_address & 0x0F00)
>> 8));
         rtn[1] = (byte)(dest_address & 0x00FF);
         rtn[2] = (byte)((expect_more_code << 6) | (byte)(priority << 4) |
            (byte)((src_address & 0x0F00) >> 8));
         rtn[3] = (byte)(src_address & 0x00FF);
         rtn[4] = (byte)((hi_protocol_code << 4) | (byte)((dest_address &
0x0F00) >> 8));
         rtn[5] = rtn[1];
         rtn[6] = (byte)((src_address & 0x0F00) >> 8);
         rtn[7] = rtn[3];
         rtn[8] = message_type;
         rtn[9] = tran_no;
         for(i = 0; i < storage_len; ++i)
            rtn[10 + i] = storage[i];

         // add the signature nullifier
         char sig_null = calcSigNullifier(calcSigFor(rtn,storage_len +
10,(char)0xAAAA));
         rtn[10 + i] = (byte)((sig_null & 0xFF00) >> 8);
         rtn[10 + i + 1] = (byte)(sig_null & 0x00FF);
         return rtn;
      }
   } //Packet class

   /** class ColumnDef
    *
    * Defines an object that holds meta-information for a column within a
    * table.  This information includes the column number, column name,
    * field type, processing string, units string, description string,
    * begin index, piece size, and array dimension information
    */
   protected static class ColumnDef
   {
      public int column_no;
      public String column_name;
      public boolean read_only;
      public byte field_type;
      public String processing;
      public String units;
      public String description;
      public int begin_index;
      public int piece_size;

      public ColumnDef(int column_no_, byte field_type_, Packet msg) throws
Exception
      {
         String alias;

         column_no = column_no_;
         field_type = field_type_;
         if((field_type & 0x80) != 0)
         {
            field_type &= 0x80;
            read_only = true;
         }
         else
```

```
            read_only = false;
         column_name = msg.read_string();
         System.out.println("Reading column " + column_name);
         alias = msg.read_string();
         while(alias.length() > 0)
            alias = msg.read_string();
         processing = msg.read_string();
         units = msg.read_string();
         description = msg.read_string();
         begin_index = msg.read_int();
         piece_size = msg.read_int();

      // we'll ignore the dimensions information and treat everything as
      // a single dimensioned array.  This greatly simplifies the math
      // involved in generating array subscripts.
         int dim = msg.read_int();
         while(dim != 0)
            dim = msg.read_int();
      } // constructor

   };

   /** class TableDef
    *
    *  Defines an object that holds the meta-information for a table.  This
    *  information includes the table name as well as column information.
    */
   protected static class TableDef
   {
      public int table_no;
      public String table_name;
      public int table_size;
      public byte time_type;
      public long interval;
      public char def_sig;
      public Vector columns;

      TableDef(int table_no_, Packet msg) throws Exception
      {
         // read the table information
         long interval_sec;
         long interval_nsec;
         int table_start_pos = msg.get_read_index();

         table_no = table_no_;
         table_name = msg.read_string();
         table_size = msg.read_int();
         time_type = msg.read_byte();
         msg.move_past(8);
         interval_sec = msg.read_int();
         interval_nsec = msg.read_int();
         interval = (interval_sec * nsecPerSec) + interval_nsec;

         // we now need to read the columns until a terminator is found
         byte field_type = msg.read_byte();
         int column_no = 1;
         columns = new Vector();
         while(field_type != 0)
         {
            ColumnDef column = new ColumnDef(column_no,field_type,msg);
            System.out.println("Read " + table_name + "." +
column.column_name);
            columns.addElement(column);
            field_type = msg.read_byte();
            ++column_no;
         }

       // the final thing that we need is to calculate the signature
       // of the table definition.  To do this we will obtain a copy
       // of the bytes from the message and calculate the signature
       // on those bytes
         byte[] table_contents = msg.get_fragment(
            table_start_pos,
            msg.get_read_index() - 1);
         def_sig =
calcSigFor(table_contents,table_contents.length,(char)0xAAAA);
      }

      public int print_records(Packet msg) throws Exception
      {
       // this method assumes that the message pointer is positioned
       // just past the table no parameter in the data collection response.
       // It will get the beginning record number and number of records
       // and will then print out the table meta-data along with field
       // values.
         int begin_record_no = msg.read_int();
         short records_count = msg.read_short();
         long record_stamp = 0;
         int rtn = begin_record_no;

         if((records_count & 0x8000) != 0)
            throw new Exception("Partial records are not supported");
         for(short i = 0; i < records_count; ++i)
         {
   // if this is an event table or if this is the first record,
   // we need to read the record stamp.
            if(i == 0 || interval == 0)
               record_stamp = (msg.read_int() * nsecPerSec);
            else
               record_stamp += interval;

            // print out the record data
            ++rtn;
            System.out.println("Data for table " + table_name);
            System.out.println("  Record: " + (begin_record_no + i));
            System.out.println("  Time: " +
getTimeStamp(record_stamp).getTime());

            // we now need to process the scalar values one at a time
            for(int j = 0; j < columns.size(); ++j)
            {
               ColumnDef column = (ColumnDef)columns.elementAt(j);
               for(int k = 0; k < column.piece_size; ++k)
               {
                  System.out.print("  " + column.column_name);
                  if(column.piece_size > 1)
                     System.out.print("(" + (column.begin_index + k) +
")");
                  System.out.print(": ");
```

```
switch(column.field_type)
{
case type_uint1:
{
   int val = ((int)msg.read_byte()) & 0xff;
   System.out.println(val);
   break;
}

case type_uint2:
{
   int val = ((int)msg.read_short()) & 0xffff;
   System.out.println(val);
   break;
}

case type_uint4:
{
   long val = ((long)msg.read_int()) & 0xffffffffL;
   System.out.println(val);
   break;
}

case type_int1:
   System.out.println(msg.read_byte());
   break;

case type_int2:
   System.out.println(msg.read_short());
   break;

case type_int4:
   System.out.println(msg.read_int());
   break;

case type_ieee4:
   System.out.println(msg.read_float());
   break;

case type_sec:
{
   long val = msg.read_int();
   System.out.println(getTimeStamp(val).getTime());
   break;
}

case type_usec:
   System.out.println("Not used by CR2xx");
   msg.move_past(6);
   break;

case type_nsec:
   System.out.println("Not used by CR2xx");
   msg.move_past(8);
   break;
```

```
                  case type_ascii:
                  {
                 // we need to read off all of the possible bytes for the
                 // string field from the data message.  This way, the
                 // pointer will be positioned at the right loc for the
                 // next field.
                     byte[] temp = msg.read_bytes(column.piece_size);

                     k += column.piece_size;      // short circuit
                                                  //loop for strings
                     for(int m = 0; m < temp.length && temp[m] != 0; ++m)
                        System.out.print((char)temp[m]);
                     System.out.println("");
                     break;
                  }

                  case type_int2_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(2);
                     break;

                  case type_int4_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(4);
                     break;

                  case type_uint2_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(2);
                     break;

                  case type_uint4_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(4);
                     break;

                  case type_nsec_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(8);
                     break;

                  case type_ieee4_lsf:
                     System.out.println("Not used by CR2xx");
                     msg.move_past(4);
                     break;

                  default:
                     System.out.println("Unsupported data type " +
column.field_type);
                     throw new Exception("Unsupported data type " +
column.field_type);
                  }
               }
            }
         }
         return rtn;
      } // print_records
```

```
         // csitype codes
         public static final byte type_uint1 = 1;
         public static final byte type_uint2 = 2;
         public static final byte type_uint4 = 3;
         public static final byte type_int1 = 4;
         public static final byte type_int2 = 5;
         public static final byte type_int4 = 6;
         public static final byte type_ieee4 = 9;
         public static final byte type_sec = 12;
         public static final byte type_usec = 13;
         public static final byte type_nsec = 14;
         public static final byte type_ascii = 11;
         public static final byte type_int2_lsf = 19;
         public static final byte type_int4_lsf = 20;
         public static final byte type_uint2_lsf = 21;
         public static final byte type_uint4_lsf = 22;
         public static final byte type_nsec_lsf = 23;
         public static final byte type_ieee4_lsf = 24;
      };
   } //PBExample class
```

Glossary

ASCII: Acronym for the American Standard Code for Information Interchange that represents the English characters as numbers, with each character assigned a number from 0 to 127.

ASCIIZ: An ASCII string that is terminated with a NULL character sequence

Binary: The numbering system computers are based on using just two unique numbers: one and zero.

BMP5 Protocol: Block Mode Protocol, Version 5. A high-level or application layer protocol used to send messages between nodes over a PakBus network.

DevConfig Protocol: A protocol used to get settings from and set settings on a CR1000 datalogger.

Hexadecimal: Refers to the base-16 number system, which consists of 16 unique symbols: the numbers 0 to 9 and the letters A to F.

LSB: Least Significant Byte. The last or rightmost byte when a binary number is written in the usual way.

Link-State Sub-protocol: A SerPkt sub-protocol used over a PakBus network to describe the communication link state of a node.

MSB: Most Significant Byte. The first or leftmost byte when a binary number is written in the usual way.

Network: A group of two or more devices linked together.

Node: A unique device on a network.

Packet: The encapsulated information allowing communication among devices on a network.

PakCtrl Protocol: A high-level protocol used to facilitate network services over a PakBus network.

PakBus: A family of protocols used to accomplish packet switched networking over a wide area using heterogeneous physical sub-nets.

Protocol: A standard or specification used to transmit data between two devices.

QuoteByte: A reserved byte, 0xbc, in the BMP5 protocol used to keep BMP5 reserved bytes from appearing within the data packet unintentionally.

SerSyncByte: A reserved byte, 0xbd, in the BMP5 protocol used to frame a data packet.

SerPkt Protocol: A common link layer protocol used over a PakBus network.

Signature Nullifier: A two-byte code that when calculated with the rest of the frame, results in a signature value of zero ensuring that the original bytes sent in the packet are the bytes received in the packet.

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