BACRouter

Data Sheet

BACnet Router, Modbus To BACnet Gateway, BBMD, Slave Proxy

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Feature:

BACRouter is a BACnet router with builtin Modbus gateway, BBMD, Slave proxy.

MS/TP:

- Two 1500V individually isolated transceivers. 15kV(Air) 8kV(contact) ESD protection, will withstand wiring errors up to 220VAC.
- Baudrates range from 9.6kbps~115.2kbps. Supports auto baudrate and baudrate forcing.
- EIA-485 A/B lines are reversible. Supports auto detect polarity from bus biasing on the fly.
- 1/8 unit load, low capacitance design, supports 256 nodes on 115.2kbps with 900m (1200m on other baudrates) cable length.
- Dip switches for 510Ω bus biasing and 120Ω termination.
- Provides option to be compatible with legacy routers that do not support extended frame.
- Supports extended feature of fast device, speed up polling master and scanning device.
- Supports slave proxy with user definable auto discovery range and scan interval.
- Supports queueing by network priority, message delay is guaranteed within 10 seconds.
- Timer with 5us granularity avoids collision and frame desynchronizing. 99.6% bandwidth utilization is achieved on 115.2kbps.
- Supports sniffer mode to analyze and record data without interfering the bus
- Detects duplicated MAC, max master, recently active MAC on the fly
- Tx and Rx LED's in each port indicates individual port status.

Ethernet:

- 10/100 Mbps half/full duplex with auto-negotiation and Auto-MDIX.
- Green LED indicate activity.

BIP:

- Supports up to 10 BACnet/IP Annex J networks on different UDP port.
- Has two compatibility options: receive global broadcast; accept unmatched destination IP.
- Supports 3 different modes: Normal, BBMD mode and Foreign Device mode.
- BBMD mode (as BACnet/IP Broadcast Management Device) supports up to 148 BDT and 148 FDT entries, supports BDT propagation to other BBMDs, supports NAT.
- Potential misconfigure of BBMD will be detected in WebUI and runtime.
- Avoid BBMD broadcast storm

Routing:

- Is designed for complicated BACnet inter-network, performance is stable even with 65534 sub-networks.
- Fast response to network topology changing, easily recover from configuration mistake.

- Avoid broadcast storm in inter-network with circular routing path.

Packet Capture:

- Supports capture on all ports (Except VBUS). Captured packets could be downloaded as Wireshark PCAP format.
- When downloading, MSTP extended frame will be converted to normal data frame that can be decoded in Wireshark.
- MSTP packets could be downloaded as "Interval format" to show exactly idle time before frame in Wireshark. It is very helpful to analyze timing and performance problem.
- Supports continuous download. Automatic traffic logging is possible with the API.
- Capture control is mapped to BACnet multi_state_value objects. The scene of problem could be locked for further analyses by program when something is going wrong.

Modbus Gateway:

- Supports TCP/RTU/ASCII slave devices.
- Two mapping modes are select-able by user: Single Device Mode; Virtual Device Mode.
- One physical slave device could be mapped to multiple logic slave devices.
- Different baudrate (1200~115200), parity (Even, Odd, None), RTU/ASCII mode slaves could co-exist on same RS485 bus.
- Due to real-time system, more slave devices are tolerated on RS485 bus without dropping performance.
- Supports up to 100 masters, 100 slaves and 1000 points.
- Supports AI/AO/AV/BI/BO/BV/MI/MO/MV BACnet object types.
- Allows up to 2048 COV subscriptions. COV notification send rate could be limited to avoid network storm.
- Convenient WebUI functions to deal with batch of mappings and slaves.
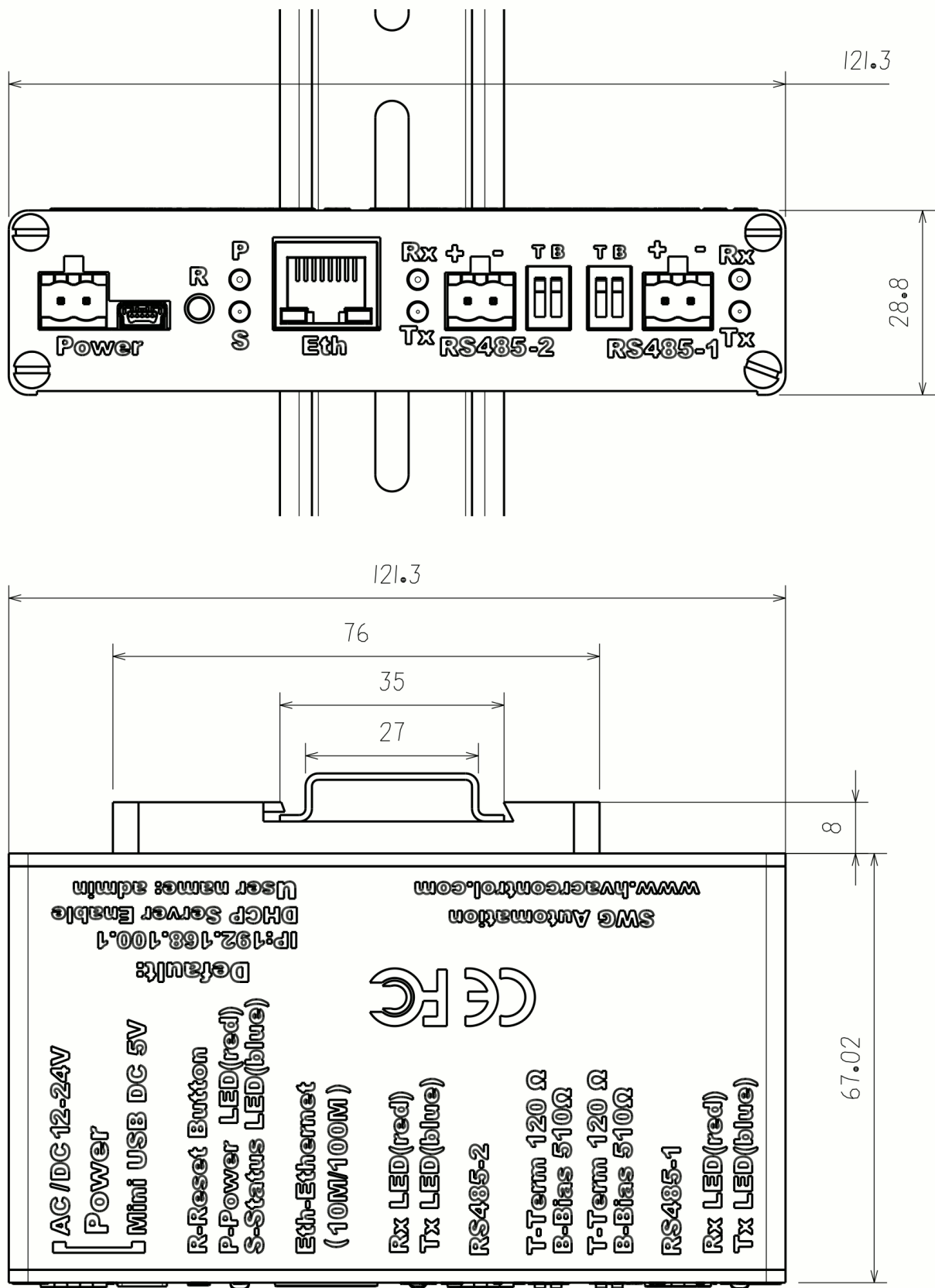- Online test/verify saves time of debug.

Commission:

- Password protected WebUI supports modern browsers: IE(10+), Edge, Firefox, Chrome, Safari.
- Supports offline configuration. Configuration could be imported from or exported to file.
- Portable size with optional powering by mini USB is suitable for on field commission.
- Easy to install with DIN rail fastener that is ready on metal case.
- Builtin DHCP server for convenient PC configuration.
- Reset button for restoring default settings.
- Power LED and Status LED indicates device status.
- Very detailed runtime info and logs are available for diagnostic purpose.

Specification：

Power supply	12~24V ±10% DC/AC (47~63HZ), removable 2-wires terminal block 5VDC, mini USB socket.
Current consumption	3W max, 60ma (typical) / 120ma (max) with 24V DC supply
Operate temperature	-10ºC~80ºC
Storeage temperature	-40ºC~90ºC
Relate humidity	0 to 95%, non condensing
Protection	IP30
Size/Weight	121mm * 75mm * 29mm metal case, 220g net
Ethernet	IEEE 802.3 10/100 Mbps data rate Half/full duplex 10BASE-T, 100BASE-TX physical layer RJ45 Ethernet Jack 100 m (max) CAT5 cable length
RS485	ANSI/ASHRAE 135 (ISO 16484-5) 9600, 19200, 38400, 57600, 76800, 115200 baudrate 1500V isolated EIA-485 interface TVS and PTC for 15kv air/8kv contact ESD protection 1/8 device load, 1200 m (max) cable length (900m on 115200bps) Removable 2 wires terminal block DIP switch for 120Ω bus terminator. DIP switch for 510Ω for bus biasing.
Regulatory Compliance	CE Mark; CFR 47, Part 15 Class B
Accessory	Three 2-wires terminals, 1m mini USB cable

Dimensions (In millimeter)：

121.3

28.8

P
R   O
○   S

Power Eth
Rx + - T B   T B + - Rx
Tx RS485-2   RS485-1 Tx

121.3

76

35

27

8

67.02

AC /DC 12-24V
Power
Mini USB DC 5V

R-Reset Button
P-Power LED(red)
S-Status LED(blue)

Eth-Ethernet
(10M/100M)

Rx LED(red)
Tx LED(blue)

RS485-2

T-Term 120 Ω
B-Bias 510Ω

T-Term 120 Ω
B-Bias 510Ω

RS485-1

Rx LED(red)
Tx LED(blue)

Default:
IP:192.168.100.1
DHCP Server Enable
User name: admin

SWG Automation
www.hvacircontrol.com

CE FC

Installation：

1. Power supply:

One of two power supply sources could be selected: AC/DC 12~24V on removable 2-wire terminal and DC 5V on mini USB socket.

2. DIN rail install:

It is easy to lock on and remove from DIN rail by slightly pushing spring buckle inside DIN rail fastener.

3. MS/TP wire:

Cable: An MS/TP EIA-485 network shall use shielded, twisted-pair cable with a characteristic impedance between 100 and 130 ohms. A additional conductor may also be used for common or signal reference where required by other BACnet devices on the same network requiring a common signal reference. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot). The shield shall be grounded at one end only to prevent ground loops occurring.

Connection: An MS/TP EIA-485 network shall use daisy-chained connections; the branch length should be as short as possible. T connections should be avoided.

Max nodes: The maximum number of devices per segment shall be 32 (for full load) , 64 (for 1/2 unit load), 128 (for 1/4 unit load) or 256 (for 1/8 unit load) . Additional nodes may be connected by the use of repeaters.

Termination: A termination resistance of 120 ohms shall be connected at each end of network segment. No other termination resistors are allowed on the intermediate devices. Notes: Termination resistor are built into the router with user select-able DIP switch.

Bias: Each MS/TP segment can be installed with network bias resistors, connected as shown in below Figure. At least one set (BACnet standard allow at most two sets, but by our experience, two sets would reduce driving capacity much), of network bias resistors shall be enable for each network segment. Each set of network bias resistors shall consist of one pull up and one pull down resistors, each having a value of 510 ohms, connected as shown in

Figure. If two sets of network bias resistors are provided, they shall be placed at two distinct nodes, preferably near the ends of the segment, so that proper bias levels can be maintained even if one of the bias nodes loses power. Note: Bias resistors are built into the router with user selectable DIP switch.
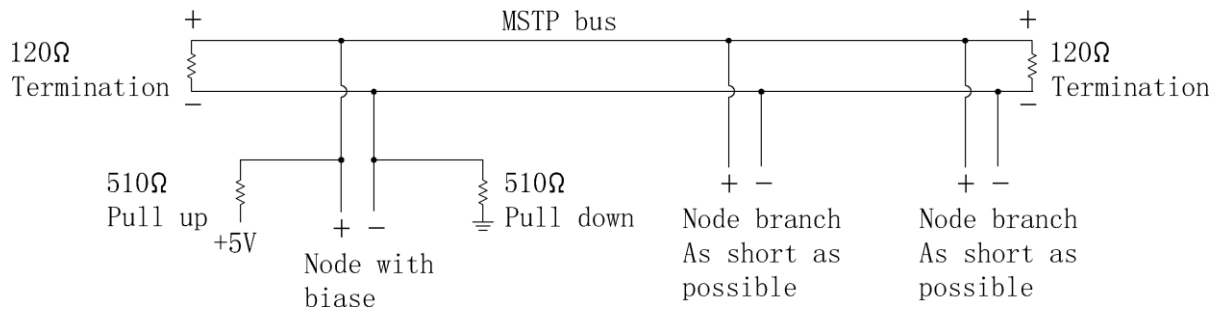

Figure 1: MS/TP Bus With Termination And Biasing

Commission:

1. Offline Configuration & Import/Export:

User could configure a BACRouter without device on hand, then export configuration to a file. When commissioning on the field, user just need to import previously exported file, "Save&Reboot" to take effect the configuration. Refer to here for detail.

2. Default Setting & Reset:

By default, the IP of router is 192.168.100.1, DHCP server is enabled, WebUI username is "admin", and password is blank.

To reset to default value, A paperclip is needed to press reset button in the small hole for more than 3 seconds and the release. The router will reboot and restore the default values.

3. WebUI & System Settings:

To access WebUI, please set PC's IP to auto assignment (Or set a static IP to the same subnet as the router if DHCP is disabled).

Connect CAT5 cable to router's RJ45 Ethernet jack. Open "http://192.168.100.1" (Use new IP of the router If it have been changed).

If this fails , please pull out CAT5 cable from RJ45 jack, wait 10 seconds then plug in to

retry.

If it succeeds, the browser will display a promote for username and password, after inputting them, the "System Settings" web page will be displayed.

Figure 2: System Settings

User name / Password: Username and password protect router from unauthorized access. Note: HTTP messages are transported as plain text. They can not withstand network sniffer, so could not be used in insecure environment.

DHCP Server: DHCP server's role is assigning IP to PC joining network, so PC need not be set a static IP manually. Note: To avoid conflict with other DHCP server, it is suggested to disable this function in production environment.

Root Password: Password for root could be used to ssh into the router for maintenance. If this password has not been set, the set button will show 「Immediately Set」 on red color, otherwise only 「Set」. Note: For security reason, please set a new password and record it before putting router on production environment.

4. General setting procedure:

Submit/Reset: There are 「Submit」 and 「Reset」 buttons on most setting page. These buttons will be enabled if any change is made. Clicking 「Reset」 button will discard all changes. Clicking 「Submit」 button will accept changes. Note: Accepted changes are stored in browser, will be lost if browser is refreshed. Only when 「Save&Restart」 button in "System Setting" page is clicked, these changes will be saved and take effect.

Save/Restart: On "System Settings" page, 「Save&Restart」 button will be enabled if there are any change submitted. Once it is clicked, the router will save all changes and try restart.

If none of IP / Network mask / Gateway / Enable DHCP is changed, the router will perform a soft restart within 5 seconds, otherwise a hard restart will be performed like power on to ensure changes take effect as user expected, it usually takes 30 seconds.

If 「Restart Router」 button on same page is clicked, the router will discard any changes and make a soft restart.

5. Config Modify From BACnet:

A few parameters could be modify by BACnet service. Those parameters will be mentioned later. If configuration is modified from BACnet, the router will automatically save to flash every 3 minutes. If the router is powered off before finishing saving, the modification will be lost.

6. LOG:

On the "System Setting" page, Clicking 「Log」 button on the top will open dialog box with log. It is helpful for trouble shooting.

```
[INFO]module_mng_init: OK
[INFO]network_init: OK
[INFO]app_init: OK
[INFO]bacnet_init: OK
[WARN]bip_port_create: bbmd not found, set to off
[WARN]bip_port_create: fd_client not found, set to false
[WARN]bvlc_bdt_push_start: bbmd not enable
[INFO]route_add_direct_entry: bind direct net(1) on port(0)
[INFO]route_add_direct_entry: bind direct net(2) on port(1)
[INFO]route_add_direct_entry: bind direct net(3) on port(2)
[INFO]route_add_direct_entry: bind direct net(4) on port(3)
[INFO]route_startup: ok
[INFO]address_init: ok
[INFO]device_init: OK
[INFO]object_init: OK
[INFO]app_startup: OK
```

清空   刷新   关闭

Figure 3: Log Dialog

7. LEDs:

Power LED is red. It will keep light once power is on.

Status LED is blue. When the route power on or hardly restart, this LED will be on for about 5 seconds, then turns off. If all initialization is finished, it will flash every 3 seconds.

8. Upgrade Firmware:

On the "System Setting" page, Clicking 「Upgrade firmware」 button on the top will open dialog box to select firmware file to upgrade.

Usually upgrading will take about one minutes. Once it is finished the web page will be automatically refreshed.

If "Keep config" checkbox is not selected before submitting, current configuration will be overwritten by default one.

The filename format of firmware is bacnet_router_X_Y.tar.gz, of which X is version number, Y is revision number.
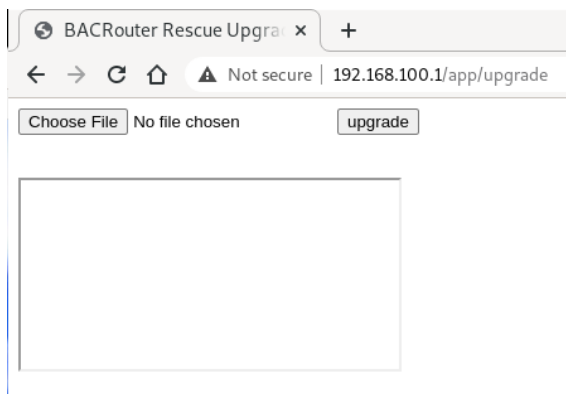
Figure 4: Rescue Upgrade
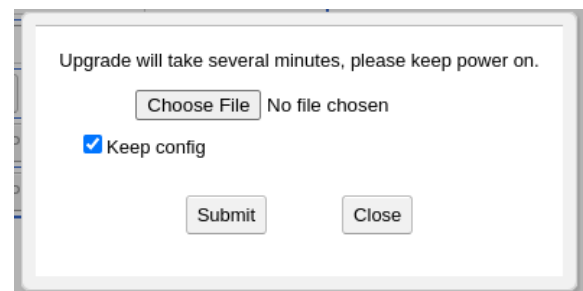
Figure 5: Upgrade Firmware

Rescue Upgrade: WebUI is complicate program built on Javascript. Sometime there may have defect in the program to prevent user from accessing the WebUI, in such situation upgrading to other version is not possible. A rescue upgrade entry is located in:

http://ip_of_BACRouter/app/upgrade   It's built with plain HTML, so it is always workable with any Web browser.

Network Settings:

Atmost of 10 ports could be created on there.

Figure 6: Network Settings

1. **VBUS Port:**

   VBUS port is virtual data link port holding up to 254 virtual BACnet devices, It's max NPDU length is 1497 bytes. It's only used for gateway functionality, for router use case, it should be deleted or disabled.

2. **Route Table:**

   Route table could be shown here. If route entries exceed limitation which is more than 1000, the excess entries will be omitted. If any network configuration is changed, this function will be disabled.

3. **Network Number:**

   In BACnet inter-network, each network has a unique network number range from 1 to 65534 (0 is for local network, 65535 is for global broadcast). If there is only one network, network number is meaningless.

   Auto Learning: BACnet addendum 135-2008g introduced network layer message types What-IS-Network-Number and Network-Number-Is. It allows the router dynamically learning network number on the fly from other routers. Setting network number as 0 will enable this feature.

   Network number could be changed by BACnet Initialize-Routing-Table service.
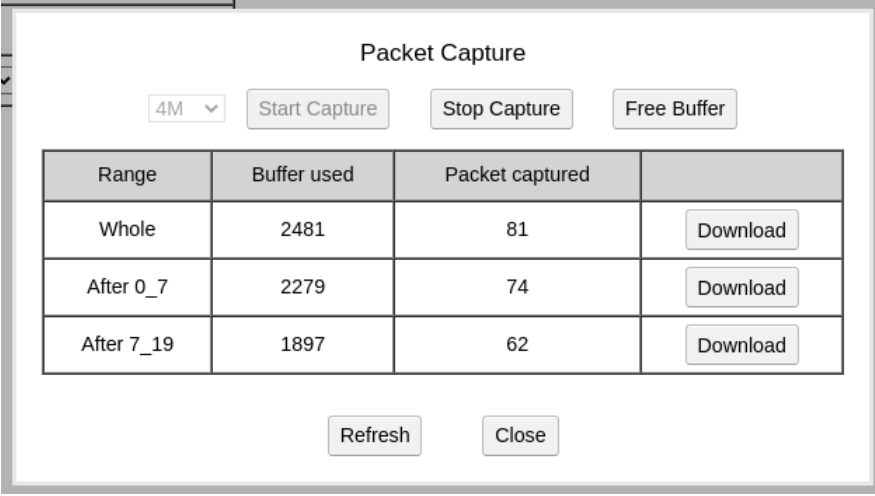
4. **Packet Capture:**

   The router supports packet capture on each enabled port. Capture could be automatically or manually started.

   Automatically Start: On a enabled port's configuration page, if a "Packet capture buffer" size is selected, packet capture will automatically start when the router restart.

   Manually Start / Stop: On a enabled port's configuration page, Clicking 「Packet Capture」 button will open a dialog box. User could change packet capture state on the fly. Note: If any network configuration is changed, the 「Packet capture」 button will be disabled.

   Packet capture state changed here will not be saved to flash.

Figure 7: Packet Capture Dialog

Continuous Download: Because of limitation of capture buffer size, if buffer is fulled, preceding packets captured will be dropped. To overcome this problem, the router saves 4 latest download records, the continuous download could follow previous.

Each download has a packet serial range, the range will be used as part of default saving filename. By refreshing the "Packet Capture" page after every download, there will have a download option with range after just finished download.

So packets captured for a long time could be downloaded as multiple files. With Wireshark, multiple cap files could be combined to single file.

Read more: https://www.wireshark.org/docs/wsug_html_chunked/ChIOMergeSection.html

Control From BACnet: If "Client mode" is disabled and "Packet capture mapping" is enabled in "Application Settings", the packet capture function will be mapped to writable multi_state_value BACnet objects.

Each route port that supports capture will has 2 multi_state_value objects. One object is for buffer size with states of "64K", "128K", "256K", "512K", "1M", "2M", "4M", "8M" and "16M". Another object is for command with states of "Stop&Clean", "Start" and "Stop".

Packet capture state changed by BACnet service will not be saved to flash.

5. General Runtime Info:
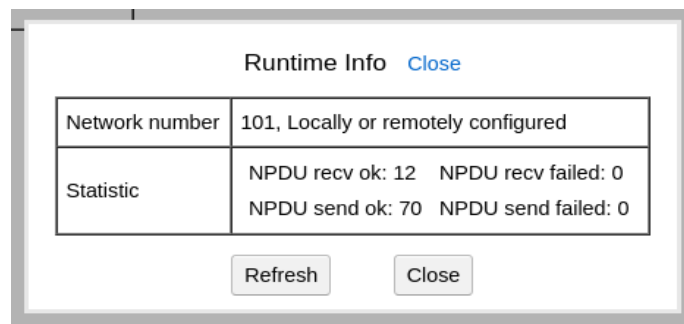
Figure 8: Runtime Info

On a enabled port's configuration page, Clicking 「Runtime Info」 button will open a dialog box for run time info. Note: If any change on any page is submitted, the 「Runtime Info」 button will be disabled.

Network Number: Network layer message types Initializing_Routing_Table and Network_Number_Is may change network number from configured value. This field shows current network number and status. There are 3 possible status: "Locally or remotely configured", "Dynamically learned", "Not configured".

BIP Related:

The IP address of BIP port will be automatically picked up from "System Settings".

1. **Receive Global Broadcast:** Some vendors (Most are Windows clients) improperly broadcast on 255.255.255.255 though BACnet standard require a subnet broadcast. The router will receive global broadcast too if this option is enabled. Note: If the mode is "Foreign device" or "BBMD" with NAT enabled, this option is unavailable.

2. **Accept Unmatched Destination IP:** According to BACnet standard, BVLL type Original-Unicast-NPDU should be sent to unicast destination, but BVLL type Original-Broadcast-NPDU should be sent to broadcast destination. Some vendors does not obey these rules, so this option could be enabled to accept these messages with unmatched destination IP. Note: If the mode is "Foreign device" or "BBMD" with NAT enabled, this option is unavailable.

Figure 9: BIP Normal Mode

3. BBMD Mode:

In IP network, IP router usually will not relay broadcast packets between subnets. To resolve broadcast problem for BIP, There should be at least one BBMD (BACnet Broadcast Manage Device) in a subnet (BACnet addendum *135-2008o* allow multiple BBMDs in a subnet, but it should be carefully configured to avoid broadcast storm. Usually only one BBMD in a subnet is still suggested) There are 2 main functions for BBMD: Relaying BACnet broadcast packet, Accepting register from foreign device.

Multiple BBMDs in subnet: If the router finds a BBMD not in local BDT (Broadcast Distribution Table), there may have multiple BBMDs in a subnet, if this feature is not enabled, the router will reject forwarded npdu from such BBMD and log error.

Interval To Push BDT: When traditional BBMD schema of only one BBMD in a subnet is implemented, BDTs in all BBMDs are identical. For convenient management of BDT, this option could be enabled on this BBMD, other BBMDs need to be set to "Accept BDT push", so any changes made to this BBMD's BDT will automatically propagate to other BBMDs. When "Multiple BBMDs in subnet" feature is enabled, this option will be unavailable.

BIP Settings

| Submit | Reset | Delete | Runtime Info | Packet Capture |

Enable	☑
Network number ?	101 1~65534, 0=Not configured
Hardware resource	eth0 ▾
Packet capture buffer(bytes) ?	4M ▾
UDP Port	47808 47808~65535
Receive global broadcast ?	☐
Accept unmatched destination IP ?	☐
Mode	BBMD ▾
multiple BBMDs in subnet ?	☐
Interval to push BDT(second) ?	0 30~65535, 0=Disable
NAT ?	0 . 0 . 0 . 0 : 47808 ☐ Enable
Cross-network broadcast support ?	☐
Accept BDT push from other	☑
Accept foreign device register	☑

Broadcast distribution table ?	IP	Distribution mask	UDP Port		
	192.168.0.1	255.255.255.255	47808	Edit	✕
	192.168.1.1	255.255.255.255	47808	Edit	✕
		+			

Figure 10: BIP BBMD Mode

NAT: When the router need to communicate with wlan, the wlan IP route may work in NAT (Network Address Translation) mode, which maps lan IP / port to wlan IP / port. This option should be enabled in such situation, the mapping wlan IP / port should be inputed in the fields. When BIP port works on NAT mode, it should not be used to communicate with other BIP devices in same lan, another BIP port could be created to communicate with these BIP devices. Note: For security reason, you SHALL run BIP over VPN on internet.

Cross Network Broadcast: This option is only available when NAT is not selected. It could be enabled if the IP router for this subnet support relaying broadcast packet. Note: Most IP routers on the market do not support this feature.

Accept BDT Push: If this option is enabled, writing to BDT from other BIP device will be allowed. Disabling it will avoid mis-writting.

Accept Foreign Device Register: If this option is enabled, registering from foreign devices will be accepted.

BDT: This field records all BBMDs. Each BBMD could be created or modified in the dialog as left. Note: This BIP port is BBMD too, it will automatically appended itself to BDT after submitting. So this BIP port need not to be input here.

BDT may be overwritten by BACnet BVLL request.

Foreign Device Table In Runtime Info:

This field in runtime info shows foreign devices registered. Each device occupies one line, the format is:

X:Y Z T, of which X is IP, Y is UDP port, Z is seconds to live, T is remaining seconds.

Figure 11: BIP Runtime Info

4. Foreign Device Mode:

Foreign device is registered to BBMD to receive BIP broadcast, local broadcast will be discarded.

Figure 12: Foreign Device Mode

Register Interval: It is time interval on which registering repeats.

Register Time To Live: It tell BBMD to keep this foreign device alive for. It is better greater than 3 times of Register interval.

MS/TP Related:

1. Basic / Extend Mode:

The BACRouter has some features extended over BACnet standard. There are 2 configuring modes: Basic one only provide features defined in BACnet standard, Extend one provide all functions.

Figure 13: MSTP Settings Basic Mode

2. Baudrate:

BACnet defines 6 baudrates: 9600, 19200, 38400, 57600, 76800, 115200. The fixed mode is standard, auto and forced modes are extended features.

Read more: http://www.hvacrcontrol.com/fixedautoforced-baudrate-for-mstp/

Figure 14: MSTP Settings Extend Mode

Auto: It is extended feature. On auto mode, when the router start, it will sniffer the bus and keep switching baudrates until it found a valid preamble of frame. Note: If the bus is idle, the router will keep waiting for data to detect baudrate.

When the route finds continuous error on running, it regards it as wrong of baudrate, start to switch baudrate to find valid preamble of frame. If the bus turns to idle in the procedure, it would turn to previous valid baudrate.

Forced: It is extended feature. The purpose is keeping bus baudrate to preset value. The mechanism of forced mode is very similar to auto mode, except 2 situations: A. If the router finds the bus is idle when it starts, it would use preset baudrate. B. When the route gets token it would switch to preset baudrate.

Device running on forced mode will force device running on auto mode to switch baudrate to preset value.

3. AB Line Polarity:

It is extended feature. If "Auto" is selected, when the router finds continuous error on running, it will swap polarity.

4. Sniffer Mode:

It is extended feature. If it is enabled, the router will just listen on the bus. All NPDUs send to / receive from this port will be dropped. All options below will be unavailable in this mode.

5. Extended Frame:

Extended mstp frame was added to standard since revision 16. There usually have inter-operation problem between extended frame enabled device and legacy router. If there is legacy router on the same bus, this feature should be disabled. However, disable extended frame feature here will still keep BACRouter compatible with extended frame enabled devices.

Read more: http://www.hvacrcontrol.com/interoperability-between-extended-mstp-frame-capable-devices-and-legacy-devices/

6. Local MAC / Max Master:

Local MAC should be unique on the bus. Max master should be equal to setting of other devices on the same bus.

To choose a unused local MAC and consistent max master, one could run the BACRouter on sniffer mode, then find proper values from "Recently active devices" and "Current max master" on the runtime info page.

Max master of first MS/TP port could be modified from BACnet.

7. Max Info Frames:

It define how many NPDUs the router would send when it hold token. The larger value

means better throughout but worse latence (Less token pass rate). The moderated value for router is 10.

Max info frames of first MS/TP port could be modified from BACnet.

By Occupy Time: It is extended feature. The NPDUs passing router usually have size between 10~50 bytes, but could be up to 501 or 1497 (Extended frame). Larger NPDU need more time to send or receive. For NPDUs which need a reply from targeted device, router has to wait for reply. Usually the targeted device need more time to handle or generate larger NPDU, router has to wait longer.

So the time the router holding token could be varied much, which impacts latency guaranty of MSTP bus. To avoid this problem, "By Occupy Time" feature limits the router's token holding time. The limitation is calculated by: byte_time * 32 * Max_info_frames.

Read more: **http://www.hvacrcontrol.com/max_info_frames-by-token-occupy-time/**

8. Fast Device:

It is extended feature. To be compatible with slow responding devices,, the BACnet standard uses lax usage timeout and reply timeout; this will seriously impact the MS/TP network bandwidth, especially on high baudrate. In addition to standard timeout, the route add a fast group timeout. A table with MAC address allows for optimal network tuning by independently selecting fast devices to use fast group timeout.

When fast device is connected by repeater, the delay including sending and receiving introduced by repeater should be counted into timeout. BACnet standard allow 2 bits time delay on each repeater and total 10 bits time delay on total path.

Fast Timeout: Poll timeout; master reply timeout and slave reply timeout define timeout for fast group.

Select Fast Devices: This field selects which device is fast device.

Figure 15: Select Fast Devices On MS/TP Bus

9. Slave Proxy:

If this feature is enabled, the router acts as proxy of "Slave devices" on application view. "Slave devices" include MS/TP slave devices and master devices which doesn't support the BACnet Who-Is function. The router obtains Device_ID, Max_APDU, Vendor_ID and Segmentation_Support from "Slave devices" by Read_Property or Read_Property_Multiple service request, and responds to Who-Is service request which matchs Device_ID of "Slave devices" by sending I-Am service with source MAC address as which "Slave device" has.

Scan Interval: The range is from 120 seconds to 65535 seconds. This parameter defines how often the router scan "Slave devices". There is two ways to scan "Slave devices", one is auto discovery, another is manual binding, we will discuss later.

Auto Discovery: If this feature is enabled, the router automatically scan all possible devices on the bus. Note: This feature will consume much bandwidth, so it's suggested to increasing scan interval; enable **Fast Device** feature or limit devices to discovery as below.

Devices To Discovery: It is extended feature. Only devices selected here instead of all devices, will be scanned in auto discovery procedure.

Manual Binding: For "Slave devices" that do not support Read_Property / Read_Propery_Multiply service request to the special device instance of 4194303, only manual binding way works. The bindings of MAC address and device instance should be defined here.

Enable/Disable of slave proxy / discovery, and manual binding may be overwritten by BACnet service.

Slave proxy	☑ Enable
Auto discovery	300 120~65535
Devices to discovery ?	Set all Unset all Set all slave Unset all slave 127 device(s) selected ☑ Show 0: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 16: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 32: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 48: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 64: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 80: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 96: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 112: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Set all Unset all 128: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 144: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 160: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 176: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 192: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 208: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 224: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑ Set all Unset all 240: ☑☑☑☑☑☑☑☑☑☑☑☑☑☑☑☐ Set all Unset all
Auto discovery	☑ Enable
Manual binding ?	MAC Address Device instance 32 10000 Edit × 33 1001 Edit × 34 1002 Edit × +

Figure 16: Slave Proxy Settings

10. Tx/Rx LEDs:

Each MSTP port has one Tx(Blue) and one Rx(Red) led. Tx led flashs when anything is sent out, so if the route has joined token passing, it will keep flashing. Rx led flashs only when

NPDU for local or broadcasted is received. If the router is on sniffer mode, Rx led will flash on any NPDU.

11. Runtime Info:

Figure 17: MS/TP Runtime Info

Token Pass Rate: It's average value for 30 seconds. The healthy value would be greater than 60.

Error Counts: There are error counts as preamble error; header error; data error; extended frame decode error; retry to pass token; failure to pass token; possible duplicated token; lost token; no answered bacnet request; no turnaround frame. If any values keep growing, there may have problem on the bus.

Current Max Master: It is dynamically detected max master value. Note: If "unmatch to local setting" is shown, there may have inconsistent max master setting on the bus.

Recently Active Other Devices: It is statistics of every received frame's source MAC for 30 seconds. Note: If any MAC is shown as red color, it may be duplicated.

Baudrate And AB Line Polarity: It is extended feature only available when baudrate mode is auto or forced; or polarity is auto. It shows current detected baudrate and polarity.

Slave Proxing: It is available when slave proxy feature is enabled. Each line here shows a device proxied. The format is:

X:Y, L, S, I:N of which X is MAC, Y is device instance, L is max apdu length, S is segmentation support, I is vendor id, N is name of manufacturer.

12. Packet Capture Characteristic:

Frame Dividing: There are 2 rules to divide frames: A. Any data following valid frame is regarded as new frame. B. Idle time more than 33 bits is regarded as start of new frame.

Read more: http://www.hvacrcontrol.com/solution-to-mstp-frame-desynchronization/

Error Handle: There are several types of error: signal noise, no stop bit, idle time between bytes too long (BACnet standard requires no more than 20 bits idle time between bytes), data verify error on header crc / data length / source MAC / data crc, incomplete frame. The data causing error and data following it will not be logged until there are new frame.

Extended Frame: Extended frame types are defined in addendum *135-2012an.* They use CRC32 to verify and COBS to encode. Extended frame of types BACnet Extended Data Expecting Reply and BACnet Extended Data Not Expecting Reply are used for BACnet NPDU transport. When the router captures extended frames, it just try to do CRC32 verification for data portion that keep encoded. Because Wireshark does not support decoding extended frames, following processor will be taken to output captured file:

If the frame type is BACnet Extended Data Expecting Reply or BACnet Extended Data Not Expecting Reply, the router would try to decoding it using COBS rule, if decoding is ok, changes the frame type to BACnet Data Expecting Reply or BACnet Data Not Expecting Reply, generates crc16. New frame will be recognized by Wireshark as normal BACnet data frame to analyze. If decoding fails, the router just generates crc16, so new frame will be recognized as a unknown valid frame by Wireshark.

For other extended frame type, the router just generates crc16. The frame will be recognized as unknown valid frame by Wireshark.
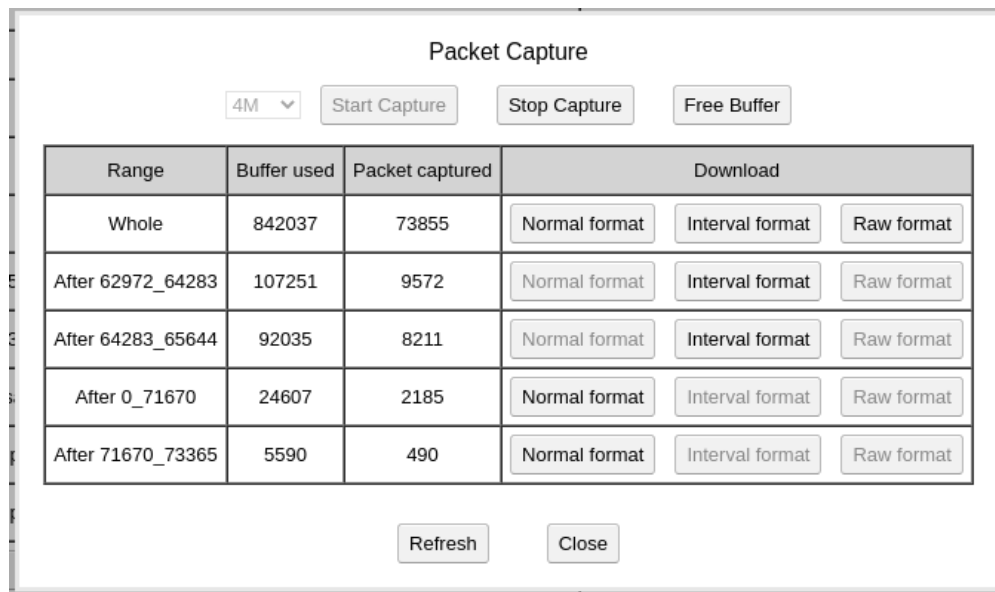
Figure 18: MS/TP Packet Capture

Interval Format: For analyzing timing and performance issue, the absolute time of packet may be insensitive but the idle time before packet may be more important. Interval format use idle time before packet as timestamp (with 5 us granularity). The downloaded filename
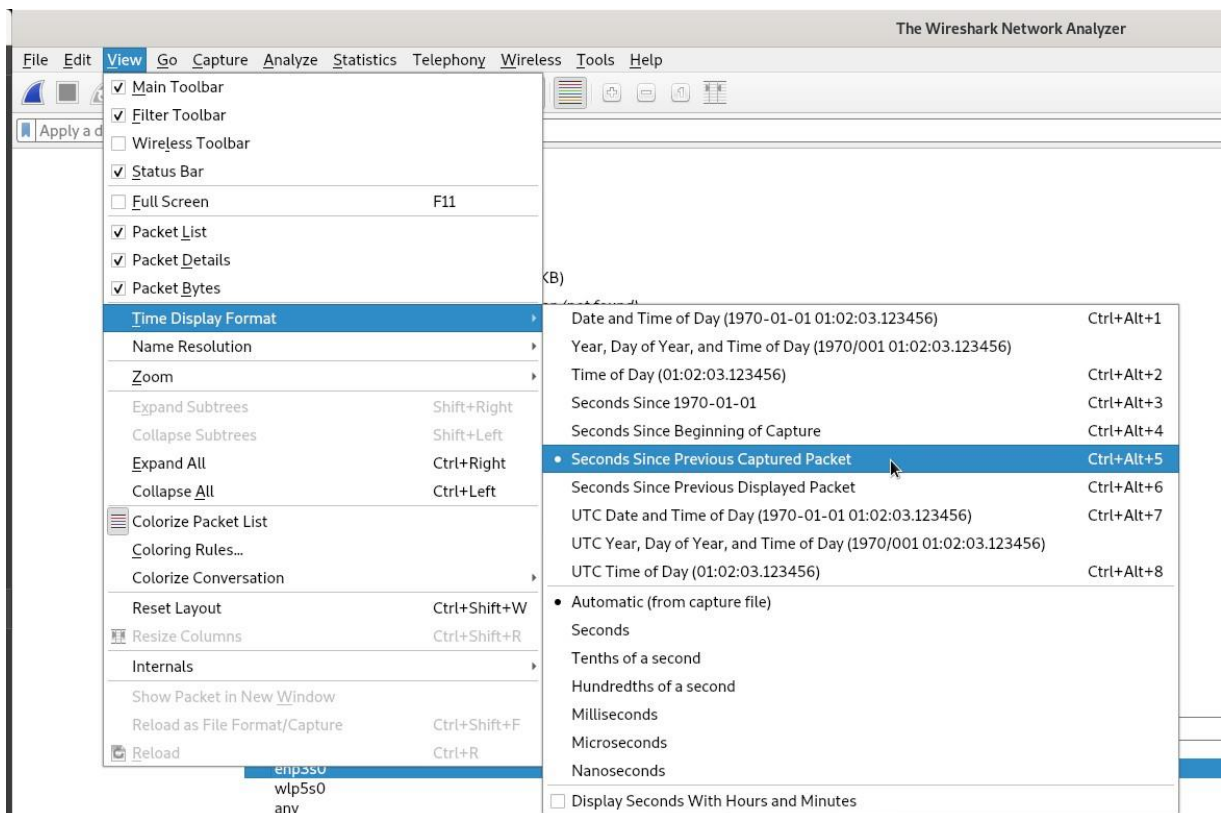
Figure 19: Set Wireshark Time Display Format For Interval Format Capture

starts with "i" (n for normal format).

To show idle time before packet,Wireshark's "Time Display Format" in the "View" top menu should be set to "Seconds Since Previous Captured Packet".

Application Setting:

Selecting 「Application」 on the left tree menu will open application settings page.

Figure 20: Application Settings

1. **APDU Timeout/Retries:**

    These parameters are writable by BACnet service. If there are virtual BACnet devices in BACRouter, all BACnet devices share same value of APDU_Timeout and Number_of_APDU_retries.

2. **Client Mode:**

    The routing function need no application layer, so this feature could be enabled to get ride of below application layer settings, if compliance to BACnet device profile is unnecessary.

3. **Device Instance:**

    The value should be unique in whole BACnet inter-network within range from 0 to 4194302. It's writable by BACnet service.

4. **Name Delimiter:**

The BACnet object name in BACRouter may be composited of several fields, for example, the BACnet object name of a Modbus mapped point may be composited of master name, slave name and point name, these fields are conjoined together by delimiter character defined here to form final object name.

5. **COV Nofity Qos:**

The BACRouter supports COV subscriptions up to 2048, so it may send out lots of COV notifications if object values with COV subscriptions are changed, especially when mapped Modbus slave get online/offline. "COV notify" and "COV notify burst" limit COV notification sending rate to avoid network storm. Note: Notification will be delayed when the sending rate reaches the limitation.

Modbus Gateway:

For detailed implementation of Modbus gateway function, please refer to:

http://www.hvacrcontrol.com/modbus-gateway-in-bacrouter/

1. **Mapping Mode:**

Single Device Mode: If VBUS port is not enabled, BACRouter will work in single device mapping mode, every Modbus slave device will be mapped into exclusive object instance space of 1000 in the only BACnet device defined in "Application Settings".

Virtual Device Mode: If VBUS network port is enabled. Each slave device will be mapped to a virtual BACnet device on VBUS network. The MAC address will start from 1. The device instance of virtual BACnet devices could be modified by BACnet service.

2. **Online Test:**

If master is enabled and configuration changing of master has been saved, then when configuring slave, online test will save a lot of time of debug.

Point Test: When editing point's mapping, there are "Test raw value" row with 「Read」button and 「Write」button if point is writable. After clicking button, "Test

result" will show result.

The raw value here means no conversion.

Figure 21: Modbus Point Test

Read Group Test: On "Read Group" dialog, 「Test」will read group(s) and show result.
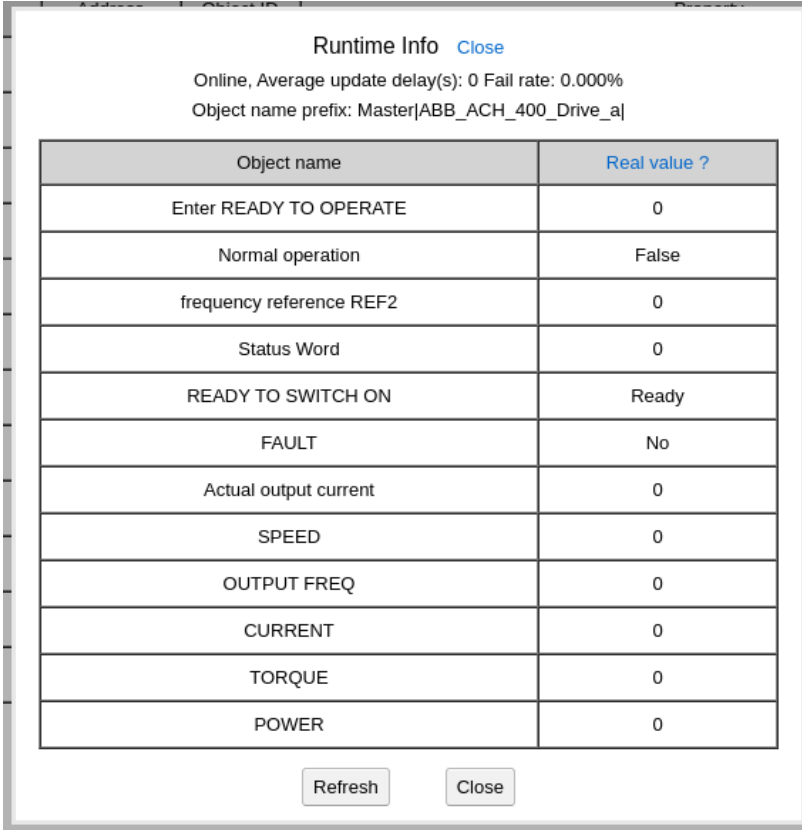
Figure 22: Modbus Read Group Test

If the slave is RTU/ASCII type, test result will include response time which may be useful to set appropriate "Reply timeout" in slave's "Modbus parameter".

3. Runtime Info:

If master and slave are enabled and the configuration changing of them has been saved,

「Runtime Info 」button will show current state of slave and points.

Figure 23: Modbus Slave Runtime Info

4. Mapping Recommend:

BACnet input or value objects are recommended for Modbus points which are not controlled through BACnet.

BACnet output or value objects are recommended for Modbus writable points which are only controlled through BACnet.

For Modbus writable points which are controlled through BACnet and other mechanism, there are three ways to integrate into BACnet:

a. BACnet value objects. The Present_Value of the value objects will be writable to mapping BACnet writing to Modbus. Modbus read back point value will update Present_Value of the value objects.

b. BACnet output objects. The Modbus read back point value will update Relinguish_Default of the output objects. Note: BACRouter doesn't support SubscribeCOVProperty service, so there is no way to get COV notification on value change of Relinguish_Default.

c. A BACnet output object and another BACnet input/value object for each Modbus point. The BACnet output object is used for command, the input/value object reflects Modbus read back value.

If a slave device represents multiple real devices, each real device has different Modbus data address, then multiple logic slave devices could be created, each logic slave device maps to a real device.

5. Batching Process Tips:

「Import CSV」 and 「Export CSV」 could be used for creating large quantity of mappings, because it's more convenient to input/edit point's name/description in Excel.

「Batch Conversion」 could be used to modify conversion of all analog objects.

「Batch Address」 could be used to modify Modbus address for multiple points.

「Import Point」 could be used to import definition of all points from configuration file of slave.

「Copy」 could be used to copy configuration of current slave/master to new one.

「Batch Import」 could be used to import all slaves from configuration file of master.

「Batch Instance」 could be used to modify object instance of all slaves.

「Batch Point」 could be used to copy definition of all points from configuration file of slave into multiple slaves.

Others:

1. Circular Route:

BACnet does not allow circular route, that means there should be exactly one route path

between any two nodes. Circular route usually causes broadcast storm and packet loss. One common causing is enabling both BIP and Ethernet for more than one device in same subnet, so there will be BIP and Ethernet paths between them. Error and warning in log will be helpful to find the misconfigure.

2. Network Number Conflict:

The network number for each network should be unique, else packet will be lost. Error and warning in log will help to diagnose it.

3. MS/TP Troubleshoot:

The most possible problem on MS/TP is **bus biasing**. Without correctly biasing, when the line is idle between packets, the voltage between AB lines will be close to 0, it become very noise sensitive. At lease one bus biasing should be guaranteed (It is easy to achieve it by turning the DIP switch of biasing on the router to on position).

Some devices will not get token with improper max master. The max master should be greater than or equal to max MAC of master device on the bus. The "Current max master" in runtime info may be checked for problem.

Other reasons include termination; mismatched baudrate; wrong AB line polarity; MAC conflict. Special care should be taken on extended feature.

4. Wireshark:

Download Wireshark from: https://www.wireshark.org/download.html

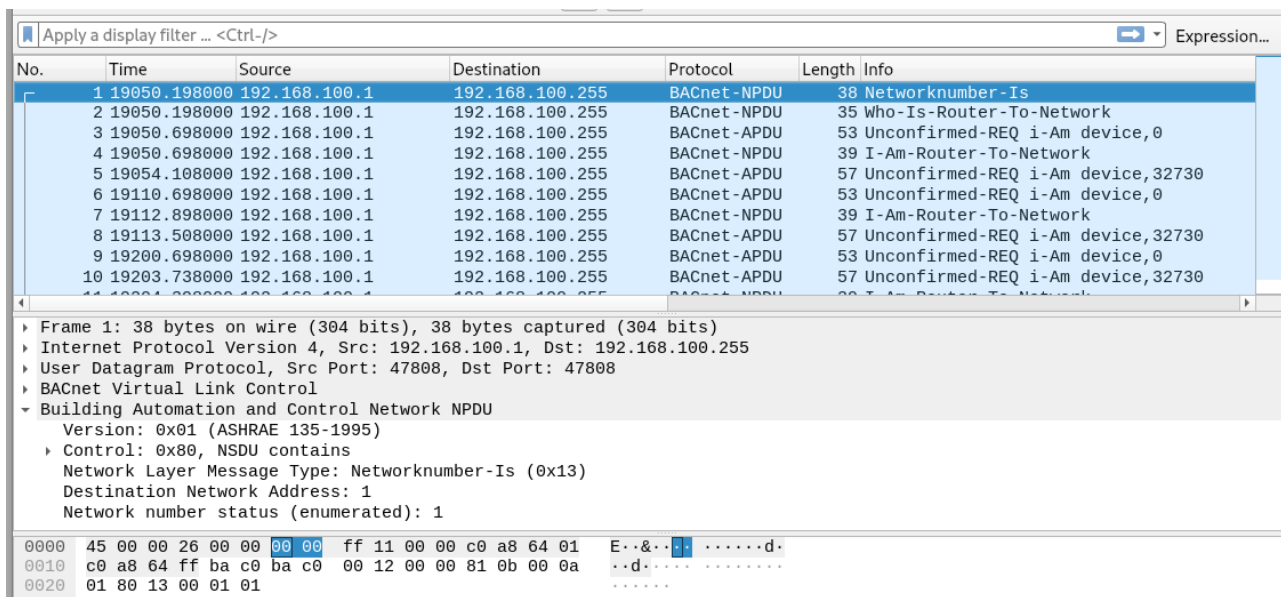After installation, captured file could be opened by Wireshark.

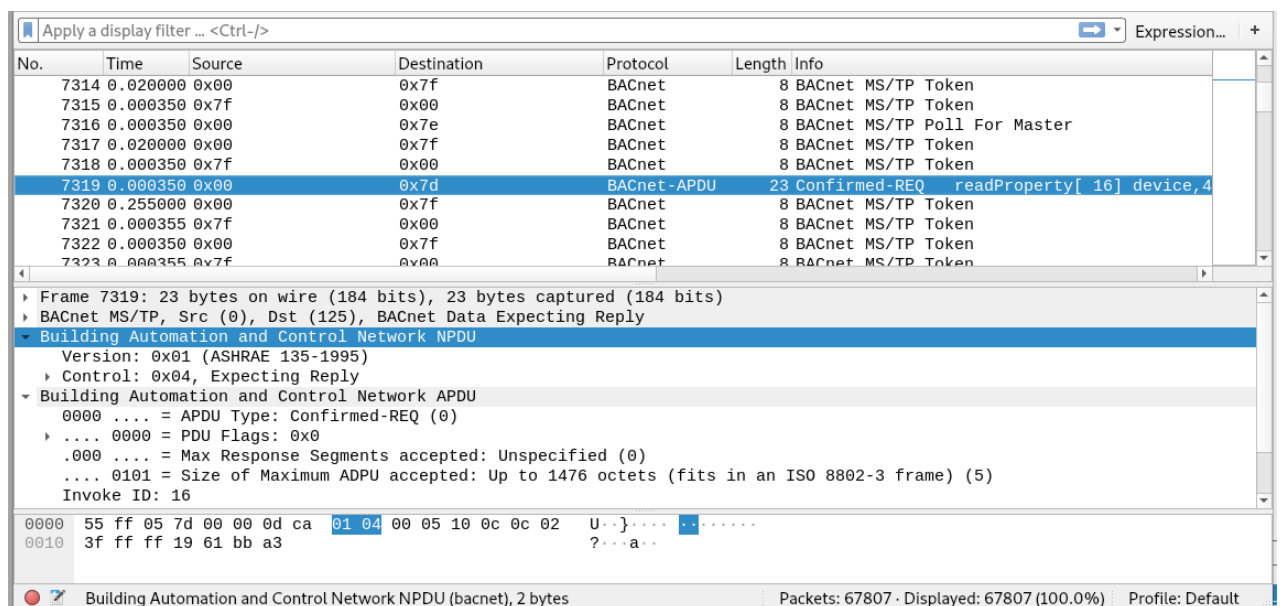*Figure 24: BIP Captured File Opened In Wireshark*

Figure 25: 115.2Kbps MS/TP Captured File Opened In Wireshark As Interval Format

5. Packet Capture API:

Automatic traffic logging for later auditing is possible with the API.

HTTP Authentication method is Digest

Read config info: http://192.168.100.1/app/config

Read capture summary: http://192.168.100.1/app/capture_summary

Read capture: http://192.168.100.1/app/read_capture

Download Python demo: http://www.hvacrcontrol.com/wp-content/uploads/api.py