RFD V4 BETA Firmware Mesh Network Forwarding Application Note

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1 Key Features

- Data forwarding to extend range or get around obstructions
- Single node relaying
- Multiple node relaying

2 Disclaimer and Limitations

The V4 BETA firmware is under active development, there may be significant changes to the operation between firmware releases. Known bugs and issues are listed in the firmware release notes. It is possible that further faults may be found during use. This firmware is to be considered experimental and should be used as such.

Any bugs, issues, general feedback or questions should be addressed to the team via email at beta@rfdesign.com.au

Note: The V4 BETA firmware is currently only configurable by AT Commands. It is not compatible with the modem tools GUI.

Note: The V4 BETA firmware is currently only compatible with the V2 hardware revision of the x series modem. See the x series modem datasheet for details on how to identify the modem hardware version if you are unsure.

3 AT Commands

The BETA firmware is currently **only configurable** by AT Commands.

The AT command mode can be entered by sending '+++', without quotes, sequence in a serial terminal connected to the radio at the correct baud rate, 57600 by default.

If successful, an 'OK' prompt will be displayed on the screen and the modem will stop displaying incoming data from the remote modem, if any.

In command mode, you can use the AT commands to control the local modem settings.

Useful commands for this application note:

AT Command	Description
ATI	Shows the firmware version and country code and hardware revision
ATI5	Shows all user settable EEPROM parameters and their values
ATI5:x:y	An alternate ATI5 command that shows the parameters in the range x to y inclusive. Example usage ATI5:6:11 will print parameters S6 through S11
ATI9	Calibration validation test
ATI10:n	Displays radio S parameter number 'n' and valid settings range.
ATI11	Show information on RC data packets sent or received, if any, depending on if the node is an RC input or RC output.
ATO	Exits AT command mode
ATSn=X	Sets radio 'S' parameter number 'n' to 'X'
ATZ	Reboots the radio
AT&F	Resets all parameters to factory defaults
AT&R	Record default PPM stream for PPM output (vehicle side)

Note: Modem parameters are saved whenever changes are made but modems need to be rebooted after any settings have been modified to activate changes.

4 LED Behaviour

Green LED
This LED indicates the modem link status and has the following patterns:
A solid green indicates that the link has been established.
A master unit flashing approximately every two seconds indicates that the unit is unlocked.
A slave unit flashing approximately every second indicates that the unit is unlocked.
A slave unit flashing approximately every half second indicates that the unit currently locking/unlocking to/from the network.
A unit flashing for one second and off for three seconds indicates that the firmware has been installed on an unsupported modem.

Red LED
This LED indicates that data received, and bootloader functions and has the following patterns:

- Flashes indicate an RF data packet received by the modem.
- Solid red indicates that the modem has entered bootloader mode.

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5 Application Configuration

5.1 Multipoint Mesh Forwarding Overview

The forwarding feature is designed to facilitate extended range operation and relaying between hidden nodes in the network.

Multipoint forwarding operations depend on the configuration of the key parameters:

- P2PAUTO
- SLOTS
- SLOTIDS
- NODEID
- BITRATE
- TOTALUS
- NETWORKS
- DESTID
- HOPSMAX
- VALIDHOPSMIN
- VALIDHOPSMAX
- FWDTABLE

Note: It is the responsibility of the user to confirm the compatibility of this firmware with local regulation and operate accordingly.

The FWDTABLE parameter is an array of forwarding table entries. Up to twenty comma separated entries can be set in the table and represent 10 pairs of source and destination nodes. Settings for the table can be configured in the following ways:

- A source address of 64 indicates a bypassed pair in the table.
- Source of 63 means forward packets from all nodes.
- Any other source values will forward data from the specific node.
- A destination of 64 indicates will use the forward destination address in the incoming packet.
- A destination value of 63 overwrites the destination of the incoming packet and instead sets the system to broadcast the forwarded data.
- Any other value overwrites the destination of the incoming packet and instead sets the destination ID to the specified node from the table.

Note: If the forwarding buffer is full and further data to be forwarded is received this newest data will be discarded.

5.2 Forwarding Examples

Each forwarding node requires enough transmission slots to provide the bandwidth to allow for the forwarding packets and, if applicable, local data.

Note: Latency increases with each hop.

There is an increase in the overhead when forwarding reducing the available bandwidth, as such it may be necessary to reduce data rate of messages or increase the bitrate of the network which may reduce range.

Note: The radio will not allow settings that result in slots smaller than ~300bytes and not larger than ~1000 bytes. BYTES~=TOTALUS*BITRATE/8000

Note: Forwarded data is prioritised over local data. So, if there is not enough total slot bandwidth to service both forwarded and local data, local data may not be transmitted or transmitted with at greater latency.

Note: Forwarding can only occur within a network i.e. only between nodes that can see each other. Therefore, it is not possible to forward data between networks or use nodes from other networks to forward data between nodes in other networks.

Forwarding nodes can have two configurations, in the first configuration the node both forwards data as per the forwarding table and, also manages local data. An example use case for this behaviour might be to have a modem that is connected to a vehicle controller as well as relaying messages for another vehicle that is operating beyond the line of sight range of the GCS modem. The second behaviour is where the node is operating as a dedicated relay node and does not have any local data.

An example 4 node network with 3 hops where **forwarding nodes also have local data**, i.e. the relay nodes are also serving as vehicle nodes, is configured by the following settings:

Master (and GCS node)

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=7	ATS8=7
SLOTIDS=1	ATS9=1
NODEID=0	ATS10=0
DESTID=63	ATS14=63
HOPSMAX=3	ATS15=3
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7

Relay and vehicle node 1 settings

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=7	ATS8=7
SLOTIDS=42	ATS9=42
NODEID=1	ATS10=1
DESTID=0	ATS14=0
HOPSMAX=3	ATS15=3
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7
FWDTABLE=0,64,2,64,3,64,	ATS49=0,64,2,64,3,64,

Relay and vehicle node 2 settings

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=7	ATS8=7
SLOTIDS=20	ATS9=20
NODEID=2	ATS10=2
DESTID=0	ATS14=0
HOPSMAX=3	ATS15=3
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7
FWDTABLE=0,64,1,64,3,64,	ATS49=0,64,1,64,3,64,

Vehicle Node 3

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=7	ATS8=7
SLOTIDS=64	ATS9=64
NODEID=3	ATS10=3
DESTID=63	ATS14=63
HOPSMAX=3	ATS15=3
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7

For bench testing it is necessary to force the modems to transmit through hops even when in rage of each other. This is done with the following settings:

Master node test settings

Setting	AT Command
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=1	ATS17=1

Relay node 1 test settings

Setting	AT Command
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=2	ATS17=2

Relay node 2 test settings

Setting	AT Command
VALIDHOPSMIN=1	ATS16=1
VALIDHOPSMAX=3	ATS17=3

Vehicle node test settings

Setting	AT Command
VALIDHOPSMIN=2	ATS16=2
VALIDHOPSMAX=3	ATS17=3

An example 3 node network with 2 hops where **the forwarding node does not have local data**, i.e. the relay node is only relaying data, is configured by the following settings:

Master (and GCS node)

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=4	ATS8=4
SLOTIDS=1	ATS9=1
NODEID=0	ATS10=0
DESTID=63	ATS14=63
HOPSMAX=2	ATS15=2
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7

Relay node 1 settings

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=4	ATS8=4
SLOTIDS=10	ATS9=10
NODEID=1	ATS10=1
DESTID=0	ATS14=0
HOPSMAX=2	ATS15=2
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7
FWDTABLE=0,64,2,64,	ATS49=0,64,2,64,

Vehicle node 2

Setting	AT Command
BITRATE=64	ATS1=64
P2PAUTO=0	ATS6=0
TOTALUS=25000	ATS7=25000
SLOTS=4	ATS8=4
SLOTIDS=4	ATS9=4
NODEID=2	ATS10=2
DESTID=63	ATS14=63
HOPSMAX=2	ATS15=2
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=7	ATS17=7

For bench testing it is necessary to force the modems to transmit through hops even when in rage of each other. This is done with the following settings:

Master node test settings

Setting	AT Command
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=1	ATS17=1

Relay node 1 test settings

Setting	AT Command
VALIDHOPSMIN=0	ATS16=0
VALIDHOPSMAX=2	ATS17=2

Vehicle node 2 test settings

Setting	AT Command
VALIDHOPSMIN=1	ATS16=1
VALIDHOPSMAX=2	ATS17=2

5.3 Encryption

The firmware supports hardware accelerated AES encryption with key lengths of 128 or 256 bits. To send and receive valid data all nodes need to have the same encryption level and key. All payload data is encrypted including RC passthrough signals.

Note: Despite being a hardware accelerated process there is some small latency associated with the encryption and decryption process.

The encryption key (K) should be a string of 32 comma separated values each with a maximum value of 255 and a final trailing comma. This represents the 256 bits of the maximum key length.

For example, the default key is:

6,61,235,16,21,202,113,190,43,115,174,240,133,125,119,129,31,53,44,7,59,97,8,215,45,152,16,163,9,20,223,244,

To enable encryption the following settings should be set:

Setting	AT Command
ENCRYPTLV=1 (128bit key), or 2 (256bit key)	ATS20=1 or 2
ENCRYPTKEY=K	ATS48=K

5.4 Multivehicle Operation Notes

- When operating multiple vehicles and/or ground control stations (GCS) on a multipoint network it is necessary to set unique SYSID for each vehicle.
- A programme such as MAVPROXY is required to coordinate the messages between the different vehicles and GCS.

6 Useful Links

FTDI USB Drivers

https://ftdichip.com/drivers/

RFD Modem Firmware and documentation

https://rfdx.atlassian.net/wiki/spaces/TS/pages/452198432/RFD+x2+Family

RFD Store

https://store.rfdesign.com.au

MAVPROXY Documentation

https://ardupilot.org/mavproxy/

7 Glossary

Term	Description
AES	Advanced Encryption Standard. A data encryption protocol meeting the specifications established in the ISO/IEC 18033-3 standard.
Baud	Unit of measurement of symbol rate. This is an indication of data transfer speed of serial connections
Throughput	Measure of data transfer speed/rate.
RX	Receive/Receiver of data transfer from an external source.
TX	Transmit/Transmitter of data to a receiver.
GCS	Ground control station
MAVLink	Micro Air Vehicle Link. A protocol for telemetry data exchange between compatible ground control software and autonomous vehicle controllers.
Latency	The time delay between signal input and output.
Serial	A protocol for sending and receiving data in a sequential manner.
RFD	RF Design. The Australian company who designed, build and support the x series modems among other products.

8 Revision History

Version	Date	Changes
1.0	21/10/24	BETA Initial Release document