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NPR - VSAT
New Packet Radio - VSAT

Protocol Specification

This specification describes the NPR-VSAT (New Packet Radio) protocol.
The main goal of this specification is to be able to implement a modem compatible to the protocol.

Version 0.2
Feb 2023

Table of contents

1 Definitions / glossary

Time Slot	Elementary time slot for TDMA allocation.
TDMA frame	Group of timeslots. The TDMA frame is the smallest repetitive scheme, where all members that need high bandwidth are allowed to transmit.
Radio frame	Elementary radio transmission, made of a preamble, sync-word, a header, and a data-field.
Burst	Finite sequence of transmission made of 1 or several radio-frames, with ramp-up at the beginning, and ramp-down at the end.
TDMA allocation	One or several consecutive time-slot on a single channel, during which a single station is allowed to transmit.
Hub	Central NPR-VSAT radio station.
Client	Client station, other stations than the Hub.

2 MF-TDMA

2.1 MF-TDMA general description

The radiofrequency resource allocated to NPR-VSAT is split in a 2D matrix made of

- Several channels, each having its own frequency, and its own symbol rate. The symbol-rate can vary from one channel to another.
    - 50kS/s
    - 100kS/s
    - 200kS/s
- Timeslots inside each channel.

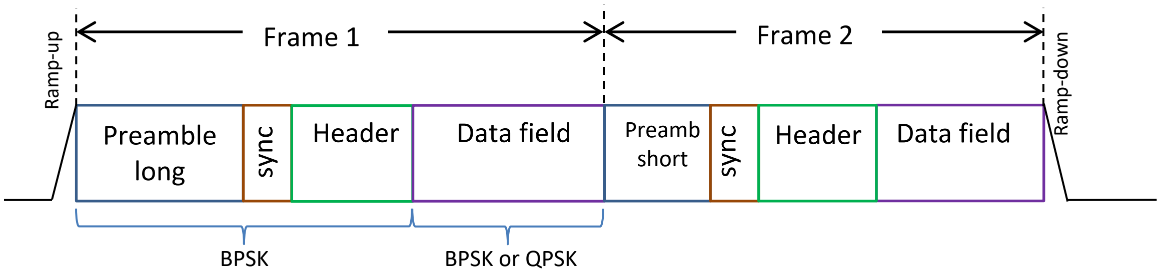
The timeslot duration is 23800 microseconds; it corresponds to a 1-frame QPSK burst with 100kS/s and with the maximum frame length, plus a slot-margin.

<table>
<tr><td></td><td colspan="5">TDMA frame 1</td><td colspan="5">TDMA frame 2</td><td colspan="4">TDMA frame 3</td></tr>
<tr><td>Time-Slot counter</td><td>1</td><td>2</td><td>3</td><td>...</td><td>16</td><td>17</td><td>18</td><td>19</td><td>...</td><td>32</td><td>33</td><td>34</td><td>..</td><td>48</td></tr>
<tr><td>Channel 1 (100kS/s)</td><td colspan="4">Hub</td><td>4</td><td colspan="3">Hub</td><td colspan="2">Client 2</td><td colspan="4">Hub</td></tr>
<tr><td>Channel 2 (100kS/s)</td><td colspan="2">Client 1</td><td colspan="3">Client 3</td><td colspan="2" rowspan="2">Client 1</td><td colspan="3">Client 2</td><td colspan="4">Discovery slot</td></tr>
<tr><td>Channel 3 (100kS/s)</td><td colspan="5">Client 2</td><td colspan="2">Client 3</td><td>4</td><td>1</td><td>3</td><td>4</td><td>2</td></tr>
</table>

2.2 Transmission burst

A transmission burst is made of

- Ramp-up: duration 320 microseconds
- One or several frames, each one containing
    - A Preamble
    - A sync word
    - A header
    - Data field
- Ramp down : duration 320 microseconds



2.3 Burst versus timeslot

Each transmission burst must fit inside the channel + the “TDMA allocation”.
The hub can allocate one or several consecutive timeslots to a single station.
The transmission burst must remain inside the duration of this TDMA allocation, but the frame organisation within the burst do not have to align with the internal borders between consecutive timeslots. Therefore, frame duration can be bigger or smaller than slot duration.

<table>
<tr><th>Time-slot counter</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td>TDMA alloc</td><td colspan="3">Client 1</td><td colspan="2">Client 2</td><td>…</td></tr>
<tr><td>Radio frames</td><td>Fr1</td><td>Frame 2</td><td>-</td><td>Frame 3</td><td></td><td></td></tr>
<tr><td>burst</td><td colspan="2">Burst client 1</td><td>-</td><td>Burst client 2</td><td></td><td></td></tr>
</table>

A station shall always try to fill as much as possible its allocation, with real data, therefore building radio-frame size which depends on the TDMA allocation (especially at the end of the allocation).

All this allocation is dynamic. The channel which a client shall use can vary from 1 allocation to the other.
In addition, a client can transmit simultaneously on several channels, depending on the “TX capability” that he declares, and depending on the radiofrequency resources allocated by the hub.

2.4 TDMA frame

It is the repetitive scheme of transmission. It is made of 16 time-slots (380.8 milliseconds).
A transmission burst will never be bigger than 1 TDMA frame.

2.5 Discovery slot

Periodically, every 8 TDMA frames, we reserve a single channel for a “discovery slot”

- Made of the 16 timeslots of a TDMA frame
- Limited to one single channel

The goal is to allow new-comers, not yet known by the VSAT-Hub, to request a new connection, via a very short frame, even if their “timing advance” is not yet fully determined.

2.6 MF-TDMA Allocation announcement

At the beginning of a TDMA-frame “N”, the Hub announces the allocation to all clients (including discovery slot) for the TDMA-frame “N+2”, in order to take into account the round-trip delay of the satellite.
Each TDMA allocation is described with

- The channel number
- Its beginning, described with “time-slot counter”
- Its duration, described in number of “time-slots”.

2.7 2 ways to organise the channels

There are currently 2 solutions for organising the channels.
With the current implementation, all channels where client transmit shall have the same Symbol Rate. This might change in future releases.

- 1st solution: 1 channel dedicated to the hub.
  The symbol rate of the Hub can be different than the other ones. Ideally, we have a dedicated 200kS/s channel to the hub.

	TDMA frame 1					TDMA frame 2					TDMA frame 3			
Time-Slot counter	1	2	3	…	16	17	18	19	…	32	33	34	..	48
Channel 1 (200kS/s)	Hub													
Channel 2 (100kS/s)	Client 1		Client 3			Client 1		Client 2			Discovery slot			
Channel 3 (100kS/s)	Client 2							Client 3		4	1	3	4	2

- 2nd solution : Hub frames interlaced
  In this solution, the hub frames are interlaced between client frames. In this case, all channels shall have the same symbol-rate

	TDMA frame 1					TDMA frame 2					TDMA frame 3			
Time-Slot counter	1	2	3	…	16	17	18	19	…	32	33	34	..	48
Channel 1 (100kS/s)	Hub				4	Hub			Client 2		Hub			
Channel 2 (100kS/s)	Client 1		Client 3			Client 1		Client 2			Discovery slot			
Channel 3 (100kS/s)	Client 2							Client 3		4	1	3	4	2

2.8 Channel Timing offset

We offset the transmission burst start in order not to trigger all burst start at exactly the same time.
Example:

- Channel 1: T0
- Channel 2: T0 + (1 x timing_offset)
- Channel 3: T0 + (2 x timing_offset)

The default value of "timing_offset" is 170 microseconds.

2.9 Fast/slow mode

The hub allocates timeslots to each client depending on its needs, its TX buffer filling (information is inside the 3rd header byte).

- If a client has a "need" higher than 2, then the Hub tries to allocate at least one timeslot per TDMA frame. It is called "fast mode".
- If a client has a need lower or equal to 2, then the Hub usually allocates one timeslot with a period greater than one TDMA-frame. Usually one timeslot every 5 TDMA frames. It is called "slow mode".

3 Physical layer

3.1 Modulation BPSK / QPSK

The modulation used inside each channel is PSK Single-Carrier. It can be BPSK or QPSK.
Currently, the authorized symbol rates are

- 50kSymbol/sec
- 100kSymbol/s
- 200kSymbol/s

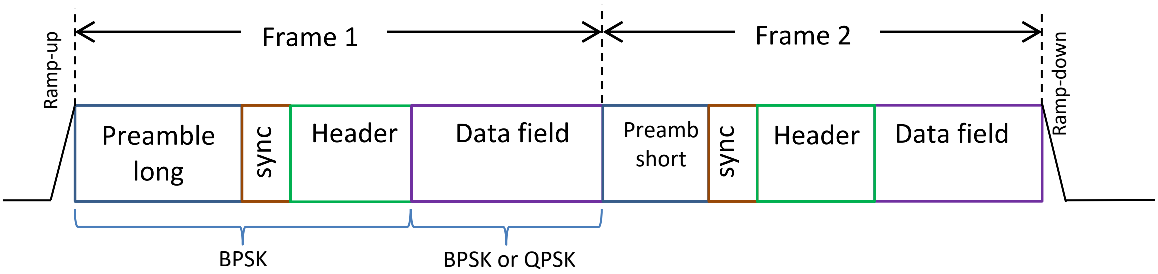
Inside a radio frame, the following parts are always sent with BPSK modulation (for robustness)

- Frame preamble
- Sync word
- Frame header

The data-field of a frame can be sent in either BPSK or QPSK modulation.

- Signaling frames and TDMA frames shall contain BPSK data-field. QPSK is not allowed. The goal is robustness.
- IPv4 frames and Null frames can have a data field either BPSK or QPSK.
  It is decided by the transmitter, depending on its "TX capability".

3.2 Radio frames



Each radio frame is made of

- A preamble
- A synchronisation word
- A header
- A data-field

3.2.1 Preamble

The preamble is made of repetitive occurrences of the 8-bits word "11001100", sent raw in BPSK mode.
The length of the preamble depends on the position of the frame inside the burst

- The first frame of the burst contains 32 of these 8-bits words
- Each consecutive frame (if any) contains 8 of these 8-bits words

During the preamble phase, the demodulator will be able to compensate the frequency offset, and to detect the symbol clock phase.

3.2.2 Sync Word

The synchronization is 2 bytes long, transmitted raw in BPSK mode.
Value : 0xBA96.
At reception, it is used to detect the beginning of a radio-frame.
The receiver-demodulator must also determine the 180° orientation of the BPSK modulation, with the help of the sync-word.

3.2.3 Frame Header

Position start	Position end	Length (bits)	Name / description
1.7	1.7	1	Top Synchro: - 1 : 1st frame of a new burst - 0 : contiguous frame inside a burst
1.6	2.0	15	Frame length Length of the data field only (in bytes), without counting CRC, without Reed-Solomon FEC.
3.7	3.0	8	3rd byte. Content depends on hub or client - Hub: time-slot counter corresponding to the beginning of the burst (=beginning of TDMA frame), for network synchronisation - Client : TX buffer filling; resolution : a 1 increment means 180 bytes.
4.7	4.5	3	Modulation - 0 : BPSK - 2 : QPSK
4.4	5.0	13	TX-ID ID of the station transmitting the frame.
6.7	6.4	4	Burst counter Incremented by 1 for each new burst, for one station, for one channel.
6.3	7.7	5	Channel ID Prevents decoding of frame on the wrong channel (due to intermodulation for example).
7.6	7.0	7	Micro-slot counter Time-slot counter corresponding to the beginning of the burst
8.7	8.0	8	Checksum Computation method: 1) Chk1 is the uint-16 sum of the 7 bytes 1 to 7 2) The final checksum is the uint-8 sum of the 2 bytes of Chk1

Position “4.7” means “byte 4, bit 7”.

3.2.4 Frame length and duration

The length of a frame can vary, in order to optimize the resource usage.
The length of the data-field can vary from 8 to 190 bytes.
(in future revision, we could allow frame length greater than 190 bytes).

The duration of a frame also varies depending on all the following parameters of the frame.

- Frame length (length of data field)
- Modulation BPSK or QPSK
- Symbol rate of the channel

Therefore, the duration of a single frame can be greater or smaller than a time-slot.

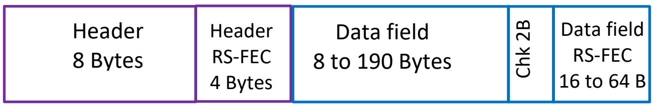
3.2.5 Client ID

The client-ID is a 13bits unique identifier, one for each station.
There are 2 specific client-ID

- Client-ID = 0: for the VSAT-Hub
- Client-ID = 0x1FFE : for not-connected client.
  These clients not connected can only transmit during the "discovery slot".

At connection, the Hub allocates a separate Client-ID for each station.
This client-ID can vary from one session to the other, for a single client station.

3.2.6 Zoom for Header and data-field



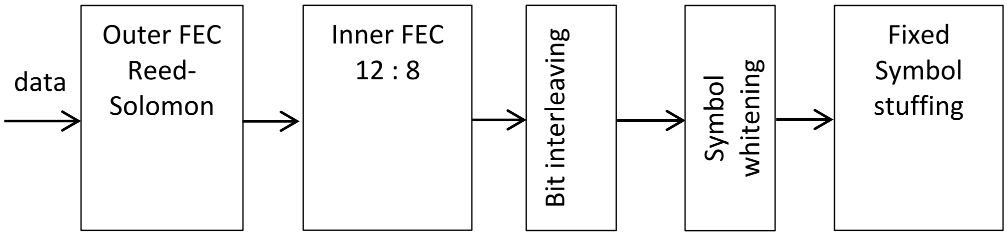
3.2.7 Data field checksum

At the end of the data-field, we have a 2-Bytes checksum.
It is the uint-16 sum of each (uint-16) pairs of bytes of the data-field.

3.3 Modulator/demodulator chain description

All the steps described below only apply for the header and the data-field of a frame. They are not applicable for the preamble and the sync-word.

Modulation part



Each of these steps applies independently for the header and for the data-field.

3.3.1 Reed Solomon Forward Error Correction (RS-FEC)

Each radio frame contains two RS FEC fields. The first one is for the frame header, the other one is for the data-field.

Common Reed-Solomon characteristics

- Word size : 8 bits
- polynomials : 1+x^2+x^3+x^4+x^8
- first root element : 19

Frame header RS-FEC

The header-RS-FEC…

- protects 8 bytes of header data (including header checksum)
- adds 4 parity bytes

Data-field RS-FEC

In order to match the variable-length principle, we adjust the length of the “Reed-Solomon FEC” field corresponding to the data field, depending on the size of the data-field itself.

We use “padding”, filling all the unused words with zeros at the beginning of the message.

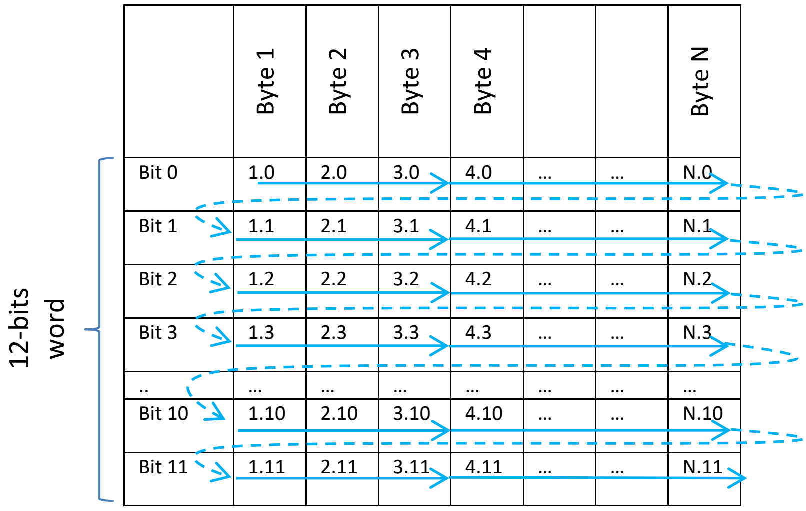
Size of data field (bytes)	**Size of data-field RS-FEC** (bytes) Parity bytes
8 to 24	8
25 to 48	16
49 to 72	24
73 to 96	32
97 to 144	48
145 to 190	64

3.3.2 Inner FEC (Hamming 12:8)

Each byte (of the header and data-fields, including RS-FEC) is protected by a hamming-code 12:8. Therefore, for each byte, we transmit a 12-bits word at output.
The code table is given in annex of the spec.
At reception, it allows to recover the right 8-bit value, with 1 bit corruption/inversion inside the 12-bits word.

3.3.3 Interleaving

The bits are transmitted via radio in the following order. The goal is to spread the "burst error" which can occur among several words, and therefore lower the probability to corrupt a word because of a single "burst error".



3.3.4 Symbol whitening

We apply whitening at symbol level.
Each symbol value is "XOR-ed" with a pseudo-random sequence.
The pseudo-random sequence is 256 words wide, and it is used cyclically.
The pseudo-random sequence is provided in annex of the spec.
This helps for spreading the spectral power density, for avoiding DC-bias, for increasing the performance of the symbol clock recovery at reception.

3.3.5 Symbol Stuffing

At fixed interval, the modulator inserts a "stuffing symbol", which has a fixed QPSK value 0b11.
The goal is to allow the de-rotator of the demodulator to correct 90° phase errors which could occur during the demodulation of a frame.
This part only applies to the "data field" of a radio frame, not to the "header".

4 Radio frame types

The data-field of a radio-frame can carry 4 types of protocols described in the table below.

Protocol name	Protocol ID	Priority	Modulation		Can be sent by…		
			BPSK	QPSK	Hub	Client Already connected	Client Not yet connected
Null-Frame	0x0	4 (lowest)	X	X	X	X	
IPv4	0x2	3	X	X	X	X	
Signaling	0xD	2	X		X	X	X
TDMA Allocation	0xE	1 (highest)	X		X		

The first 3 bytes of data field of frames are always organized in the same way, whatever the protocol.

Position start	Position end	Length (bits)	Name / description
1.7	2.0	16	Destination ID
3.7	3.4	4	Protocol ID Value: 0xE = "TDMA allocation"
3.3	3.0	4	Reserved (for future use)

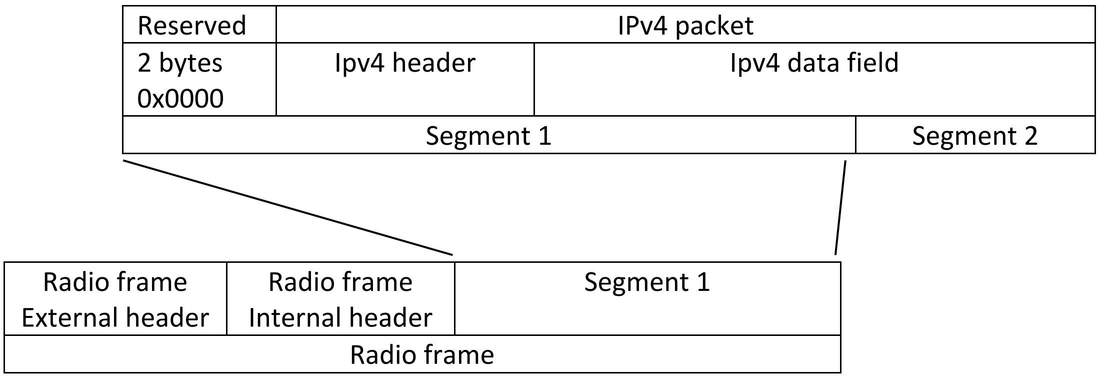
4.1 Null frames

Null frames contains no useful data except for their Header, they are used in 2 cases

- Sent by a client station, at the beginning of its allocation, in case no other data to be sent (no IPv4, no Signalling). The goal is to keep synchronisation
    - TX-Power measurement
    - Timing-Advance measurement
- Sent by the hub, in configuration with 1 channel dedicated to the hub downstream.

4.2 IPv4 frames

The protocol carries IPv4 packet without the Ethernet header.
We add 2 bytes at the beginning/left of each IPv4 packet. It is currently reserved for future usage. (the goal would be to allow routed subnet, and the 2 bytes would carry the IPv4 address of the next-hop router).



An IPv4 packet can be segmented into several radio-frames, if it is too big to fit inside one single radio-frame. The segmentation mechanism is described in the table below. Each segment is then encapsulated inside one single radio-frame.

Warning, because a station can transmit simultaneously on several channels, segments of a single IPv4 packet can arrive out of order. The receiver shall be robust with that, and reconstruct IPv4 packet even in case of out-of-order segments reception.

Position start	**Position end**	**Length (bits)**	**Name / description**
1.7	2.0	16	<u>Destination ID</u> Value: 0x1FFF = broadcast
3.7	3.4	4	<u>Protocol ID</u> Value: 0x2 = “IPv4”
3.3	3.0	4	<u>Reserved</u> (for future use)
4.7	4.0	8	<u>Packet counter</u> Incremented by 1 for each new IPv4 packet. There is one separate packet counter for each pair [TX-ID → destination-ID]
4.7	4.7	1	<u>Last segment</u> - Value 0: it is not the last segment of the IPv4 packet, more to come. - Value 1: it is the last segment of an IPv4 packet
4.6	4.0	7	<u>Segment counter</u> Zero : 1st segment of an IPv4 packet Incremented by 1 for each following segments.

4.3 TDMA allocation frames

The table below shows the data-field of a TDMA-allocation frame.
The example below shows a TDMA allocation frame, sent by the VSAT-Hub, for 2 allocations.

	Position start	**Position end**	**Length (bits)**	**Name / description**
	1.7	2.0	16	Destination ID Value: 0x1FFF = broadcast
	3.7	3.4	4	Protocol ID Value: 0xE = “TDMA allocation”
	3.3	3.0	4	Reserved (for future use)
TDMA alloc 1	4.7	5.3	13	Client ID (of the TDMA allocation)
	5.2	6.5	6	Channel (of the TDMA allocation)
	6.4	6.0	5	Duration (of the TDMA allocation) Unit : 1 means 1 slot (23.8ms)
	7.7	7.8	8	Beginning (of the TDMA allocation) Unit : 1 means 1 time-slot (23.8ms)
TDMA alloc 2	8.7	…		
	…	11.0		
	12.7	13.0	16	End-Of-Frame mark. Value : 0xFFFF

Position “4.7” means “byte 4, bit 7”.

4.4 Signalling

The data-field of a signalling frame is organised with a TLV structure (type-length-value).

	Position start	Position end	Length (bits)	Name / description
	1.7	2.0	16	Destination ID Value: 0x1FFF = broadcast
	3.7	3.4	4	Protocol ID Value: 0xD = "Signaling"
	3.3	3.0	4	Reserved (for future use)
Signalling message 1	4.7	4.0	8	Message type
	5.7	5.0	8	Message length
	6.7	(5+N).0	N	Content / values.
Signalling message 2				Message type
				Message length
				Content / values.
			16	End-Of-Frame mark. Value : 0xFFFF

Position "4.7" means "byte 4, bit 7".
The "message length" value counts bytes in the "content / value" section only.

Summary of the signalling message types

Type	Length (bytes)	Sent by..			Description
		Hub	**Client already connected**	**Client not yet connected**	
0x01	23	X	X		Who
0x05	25		X	X	Connection request
0x06	27	X			Connection acknowledge
0x07	21	X			Connection NACK
0x11	5	X			RF channel characteristics
0x12	8	X			Timing characteristics
0x21	13	X			IPv4 general configuration
0x22	variable	X			IPv4 Static routing information
0x24	Variable N x 6	X			IPv4 ranges

4.4.1 Signalling message Who

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x01 “Who”
2	2	1	Message Size Value = 23
3	4	2	Client ID
5	20	16	Callsign
21	21	1	IP static (reserved for future usage)
22	23	2	IP-Begin Start of the IPv4 address range allocated to the station. Only the 2 “least significant bytes” are represented (the 2 most significant bytes are common between all stations).
24	25	2	IP-Size (uint-16) Size of the IPv4 address range of the station

4.4.2 Signalling message Connection request

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x05 “Connection request”
2	2	1	Message Size Value = 25
3	6	4	Random number A random number constant at one station, stored in “NVRAM”.
7	22	16	Callsign
23	23	1	IP static (reserved for future usage)
24	25	2	IP-Size requested (uint-16) Size of the IPv4 address range requested by the station
26	26	1	TX-capability For detailed definition, refer to the NPR-VSAT user guide
27	27	1	RX-capability Currently not used, reserved for future usage

4.4.3 Signalling message Connection Acknowledge

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x06 “Connection acknowledge”
2	2	1	Message Size Value = 27
3	6	4	Random number A random number constant at one station, stored in “NVRAM”.
7	22	16	Callsign
23	24	2	Client-ID Client ID assigned by the hub.
25	25	1	IP static (reserved for future usage)
26	27	2	IP-Begin Start of the IPv4 address range allocated to the station. Only the 2 “least significant bytes” are represented (the 2 most significant bytes are common between all stations).
28	29	2	IP-Size (uint-16) Size of the IPv4 address range allocated to the station

4.4.4 Signalling message Connection NACK (connection refused)

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x07 “Connection NACK”
2	2	1	Message Size Value = 21
3	6	4	Random number A random number constant at one station, stored in “NVRAM”.
7	22	16	Callsign
23	23	1	NACK-reason Reason of the rejection - 0x02 : no IP resource available left - 0x03 : too many clients connected - 0x04 : IP size requested by client is too big

4.4.5 Signalling message RF channel characteristics

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x11 "RF channel characteristics"
2	2	1	Message Size Value = 5
3	3	1	Channel number ID of the channel currently being described Starts with channel zero.
4	4	1	Symbol rate - 0x00: 100kS/s - 0x01: 50kS/s - 0x02: 200kS/s
5	6	2	Frequency (uint-16) Frequency of the channel being described.
7	7	1	Total channel count

The Hub shall send this signal for all channels.
A client station only considers these information to be exhaustive and reliable when it receives 2 times (for confirmation) the description of each channel.

4.4.6 Signalling message Timing characteristics

Position start	Position End	Size (bytes)	Name/description
1	1	1	Message Type Value = 0x12 "Timing characteristics"
2	2	1	Message Size Value = 8
3	5	3	Slot duration (uint-24) Duration of a single slot. Unit : µs.
6	7	2	Slot Margin (uint-16) Unit : µs
8	8	1	TDMA frame length It counts the slots inside one TDMA frame (16 by default)
9	10	2	Channel timing offset (uint-16) Unit: µs We offset the transmission burst start in order not to trigger all burst start at exactly the same time. Example: - Channel 1: T0 - Channel 2: T0 + (1 x timing_offset) - Channel 3: T0 + (2 x timing_offset)

4.4.7 Signalling message IPv4 general configuration

Position start	**Position End**	**Size (bytes)**	**Name/description**
1	1	1	Message Type Value = 0x21 "IPv4 general configuration"
2	2	1	Message Size Value = 13
3	6	4	Client modem IP address The address is the same for all client virtual modem. This IP is mostly used for the DHCP server inside the client virtual modem.
7	10	4	Subnet Mask
11	11	1	DNS active - 0x00 : DNS is inactive - 0x01 : DNS is active
12	15	4	DNS server IP address

4.4.8 Signalling message IPv4 Static routing information

Position start	**Position End**	**Size (bytes)**	**Name/description**
1	1	1	Message Type Value = 0x22 "IPv4 Static routing information"
2	2	1	Message Size Value = variable
3	N+2	N	Static routing information Data are presented in exactly the same way as "DHCP option 121". The "length" field of "DHCP option 121" is not repeated, the "NPR-VSAT signalling message size" is used instead.

4.4.9 Signalling message IPv4 ranges

	Position start	Position End	Size (bytes)	Name/description
	1	1	1	Message Type Value = 0x24 “IPv4 ranges”
	2	2	1	Message Size Value = variable N x 6 Where N is the number of ranges described in the single signalling message
IP range description 1	3	4	2	Client ID
	5	6	2	IP-Begin Start of the IPv4 address range allocated to the station. Only the 2 “least significant bytes” are represented (the 2 most significant bytes are common between all stations).
	7	8	2	IP-Size (uint-16) Size of the IPv4 address range allocated to the station
IP range descr 2	9	10	2	Client ID
	11	12	2	IP-Begin
	13	14	2	IP-Size

The example above is for a single message describing 2 IPv4 ranges. The 6-Bytes structure can be repeated more than 2 times.

5 Annex 1: pseudo random sequence for whitening

```
whitening_pattern[256] = {
       2,2,2,3,2,2,3,1,2,0,1,3,1,2,3,0,0,0,3,1,3,1,1,2,3,1,1,1,2,2,0,0,
       0,1,1,1,1,3,3,1,1,3,2,0,0,2,1,3,1,3,2,1,1,3,0,0,2,2,3,2,3,3,0,2,
       3,1,2,1,1,2,1,1,3,1,0,3,2,0,2,2,3,3,3,2,0,1,3,0,2,2,0,3,0,2,1,0,
       0,0,3,0,3,0,1,1,3,0,1,2,3,3,1,3,2,0,1,2,0,3,2,3,3,1,2,2,1,1,1,0,
       2,2,0,2,0,3,1,3,0,1,3,3,2,1,0,2,1,1,1,1,2,3,0,1,0,2,1,0,1,0,2,0,
       0,0,0,1,0,1,0,3,0,1,0,3,1,1,1,3,2,1,0,3,1,0,1,2,2,2,0,2,1,3,0,3,
       3,1,2,3,1,0,1,3,2,3,0,1,1,2,0,0,2,0,3,0,3,1,1,0,3,3,1,3,3,0,0,2,
       3,3,3,3,0,0,3,3,2,3,0,0,1,3,0,3,2,1,3,3,2,0,0,3,1,2,1,0,2,0,1,0
};
```

6 Annex 2: Hamming (12,8) table

```
FEC_dico_fwd[256] = {
       0x001,0x006,0x018,0x01F,0x02A,0x02D,0x033,0x034,
       0x04B,0x04C,0x052,0x055,0x060,0x067,0x079,0x07E,
       0x180,0x187,0x199,0x19E,0x1AB,0x1AC,0x1B2,0x1B5,
       0x1CA,0x1CD,0x1D3,0x1D4,0x1E1,0x1E6,0x1F8,0x1FF,
       0x282,0x285,0x29B,0x29C,0x2A8,0x2AF,0x2B1,0x2B6,
       0x2C9,0x2CE,0x2D0,0x2D7,0x2E3,0x2E4,0x2FA,0x2FD,
       0x303,0x304,0x31A,0x31D,0x329,0x32E,0x330,0x337,
       0x348,0x34F,0x351,0x356,0x362,0x365,0x37B,0x37C,
       0x483,0x484,0x49A,0x49D,0x4A9,0x4AE,0x4B0,0x4B7,
       0x4C8,0x4CF,0x4D1,0x4D6,0x4E2,0x4E5,0x4FB,0x4FC,
       0x502,0x505,0x51B,0x51C,0x528,0x52F,0x531,0x536,
       0x549,0x54E,0x550,0x557,0x563,0x564,0x57A,0x57D,
       0x600,0x607,0x619,0x61E,0x62B,0x62C,0x632,0x635,
       0x64A,0x64D,0x653,0x654,0x661,0x666,0x678,0x67F,
       0x781,0x786,0x798,0x79F,0x7AA,0x7AD,0x7B3,0x7B4,
       0x7CB,0x7CC,0x7D2,0x7D5,0x7E0,0x7E7,0x7F9,0x7FE,
       0x888,0x88F,0x891,0x896,0x8A2,0x8A5,0x8BB,0x8BC,
       0x8C3,0x8C4,0x8DA,0x8DD,0x8E9,0x8EE,0x8F0,0x8F7,
       0x909,0x90E,0x910,0x917,0x923,0x924,0x93A,0x93D,
       0x942,0x945,0x95B,0x95C,0x968,0x96F,0x971,0x976,
       0xA0A,0xA0D,0xA13,0xA14,0xA20,0xA27,0xA39,0xA3E,
       0xA41,0xA46,0xA58,0xA5F,0xA6B,0xA6C,0xA72,0xA75,
       0xB8B,0xB8C,0xB92,0xB95,0xBA1,0xBA6,0xBB8,0xBBF,
       0xBC0,0xBC7,0xBD9,0xBDE,0xBEA,0xBED,0xBF3,0xBF4,
       0xC0B,0xC0C,0xC12,0xC15,0xC21,0xC26,0xC38,0xC3F,
       0xC40,0xC47,0xC59,0xC5E,0xC6A,0xC6D,0xC73,0xC74,
       0xD8A,0xD8D,0xD93,0xD94,0xDA0,0xDA7,0xDB9,0xDBE,
       0xDC1,0xDC6,0xDD8,0xDDF,0xDEB,0xDEC,0xDF2,0xDF5,
       0xE89,0xE8E,0xE90,0xE97,0xEA3,0xEA4,0xEBA,0xEBD,
       0xEC2,0xEC5,0xEDB,0xEDC,0xEE8,0xEEF,0xEF1,0xEF6,
       0xF08,0xF0F,0xF11,0xF16,0xF22,0xF25,0xF3B,0xF3C,
       0xF43,0xF44,0xF5A,0xF5D,0xF69,0xF6E,0xF70,0xF77
};
```