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NPR
New Packet Radio

Protocol Specification

This specification describes the NPR (New Packet Radio) protocol.
The main goal of this specification is to be able to implement a modem compatible to the protocol.
This specification only describes the "radio" part of the protocol. It does not describe the link between one modem and the computers connected to it (neither for data transport nor for management).
One proposed implementation of a NPR modem is the 'NPR 70 v02 modem', refer below:
https://hackaday.io/project/164092-npr-new-packet-radio

This specification does not describe general information about NPR. For such information, please refer to "NPR advanced user guide"
https://hackaday.io/project/164092-npr-new-packet-radio

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1 Definitions / glossary

Time Slot	Time interval where only one modem of the network is allowed to send data over radio. This member can send one or several radio frames during this time slot.
Microslot	Time interval which corresponds to the maximum duration of a radio frame.
TDMA frame	Group of timeslots. The TDMA frame is the smallest repetitive scheme, where all members that need high bandwidth are allowed to transmit.
(TDMA) multi frame	Group of TDMA frames, formed in a repetitive scheme that lasts more than one TDMA frame. The goal is to introduce time slots which period is bigger than one TDMA frame.
Radio frame	Radio transmission which stats with a preamble, then sync word, and then data field.
Modem	NPR device (station) which plays the role of transceiver and modem at the same time.
Master	Central NPR radio station, in a 'point to multipoint' topology
Client	Peripheral NPR radio station in a "point to multipoint" topology.
Downlink	All the radio transmission from master to clients
Uplink	All the radio transmission from clients to master

2 General organisation

The diagram below shows the organisation and encapsulation of all kind of information transported by the NPR protocol.

Data	Useless data	IPv4 Packet (1500 bytes maxi)	TDMA allocation from Master to Clients	Radio connection transactions	Who
Intermediate protocol (optional)		Segmentation (254 bytes of raw data)		TLV aggregation	
Protocol type	0x00 NULL	0x02 IPv4	0x1F TDMA allocation	0x1E Signalling	
	FEC (Forward Error Correction)				
	NPR radio frame structure (common to all frames)				

3 Radio physical layer

The modulation is either GMSK or 4-levels-GMSK (named bellow 4GMSK) depending on the selected "modulation".
Several standard symbol rates and modulation types are provided.

Symbol Rate	**Modulation**	
	2GMSK	**4GMSK**
180kS/s	Not available	Configuration 22 360kbps
300kS/s	Configuration 13 300kbps	Configuration 23 600kbps
500kS/s	Configuration 14 500kbps	Configuration 24 1Mbps

Lots of parameters (timings, period, max number of slots and clients) depend on these 2 modulation characteristics (Symbol rate and modulation). Therefore, only these 5 modulations are available

3.1 Coding

The coding for 4-levels GMSK:

	Deviation value for modulation…		
2 bits value	**… 22**	**… 23**	**… 24**
0b00	- 45 kHz	- 75 kHz	- 125 kHz
0b01	- 15 kHz	- 25 kHz	- 41.67 kHz
0b11	+ 15 kHz	+ 25 kHz	+ 41.67 kHz
0b10	+ 45 kHz	+ 75 kHz	+ 125 kHz

The coding for 2 levels GMSK:

	Deviation value for modulation…	
Bit value	**… 13**	**… 14**
0b0	- 75 kHz	- 125 kHz
0b1	+ 75 kHz	+ 125 kHz

3.2 Basic radio frame structure:

Preamble (always 2GMSK)	Sync Word	Remaining…

If one modem has to send more information than one radio frame can contain, then it must send several consecutive radio frames, each one containing its own preamble, sync word, etc…

3.3 Preamble:

The preamble is made of repetition of '0b1010' symbols (2GMSK equivalent). In case of a 4GMSK modulation configuration, this preamble is sent with 2GMSK modulation (only outer-maximum deviation are used).

The length of the preamble can vary. The very first radio frame sent by one modem inside its time slot is longer than following radio frames. The purpose is to adapt to some RF DMR amplifier which require some time to trigger.
Refer to annex 1 for min/max preamble lengths.

3.4 Data whitening

Part of the frame is whitened using the following algorithm.
The mechanism is 'IBM data whitening' with:

- Polynomial = X9 + X5 + 1
- Seed = 0xFF

Please refer to NXP Application Note AN5070. The implementation corresponds exactly to the example given at §5.2.1 of this application note.

4 Radio Link Layer

4.1 Common radio frame structure

The following radio frame structure is common, whatever the protocol carried by the radio frame at upper layer.

	Position (byte)	content	Protected With… Parity bit	FEC	Whitening	Comment
		(Preamble)				
Not protected by FEC	1	Sync word 1st Byte				Value : 0xA2 (SI4463 API : 0x45)
	2	Sync word 2nd Byte				Value : 0x4B (SI4463 API : 0xD2)
	3	Network ID				
	4	Length			X	
	5	TDMA Byte	X		X	
Protected by FEC	6	Client ID	X	X	X	
	7	Protocol		X	X	
	8	(Segmenter byte)		X	X	(Optional, only for IPv4)
	9 …	Remaining of Frame (depends on protocol)		X	X	

4.2 Data protection (parity bit and / or FEC)

The NPR protocol uses 2 types of data protection

- Parity bit
- FEC

Warning: the "client ID" field is protected 2 times: with FEC and with parity bit.

4.2.1 Parity bit

2 bytes in each radio frame carry a parity bit in their most significant bit. The goal is to detect data corruption in these bits rapidly on receiver side, before FEC decoding.

The parity bit is always "even parity". It means that the sum of all 8 bits inside this byte must be "even" in order the byte to be valid.

4.2.2 FEC (forward error correction)

A big part of each radio frame is protected with a FEC mechanism, which helps to detect data corruption and helps to correct data corruption (in some situations).
Warning, the FEC only protects part of the radio frame. The first bytes are not protected, because these bytes are computed, interpreted in real time tasks (just before transmission, just after reception), whereas FEC is computed inside "best effort" tasks.
Currently, the FEC mechanism is based on XORing, which is a very simple mechanism.
The raw content of the radio frame which must be protected with FEC algorithm is split into 3 parts, which have the same length. If the raw data length is not a multiple of 3, it is augmented to reach the next multiple of 3.
For each of the 3 parts, the FEC encoder adds a CRC byte at the end of each part; this CRC is just a XOR of each byte of the raw part. With this CRC, the receiver can detect if data corruption occurred in one or several of the 3 parts.
The FEC encoder adds a 4th part to the frame. Each byte of this 4th part is a XOR or the 3 bytes of each raw parts, which have the same position.
This 4th part (the XOR part) has also a CRC to detect data corruption.
If the radio frame is received with 1 of the 3 first parts corrupted, then the receiver can rebuild the corrupted part with the XOR part, and the 2 uncorrupted parts.

Raw, unprotected data:

position	Data
1 … N	1st part
N+1 … 2.N	2nd part
2.N +1 … 3.N	3rd part

Data with FEC:

Position	Data
1 … N	1st part
N+1	CRC 1
N+2 … 2.N+1	2nd part
2.N+2	CRC 2
2.N+3 … 3.N+2	3rd part
3.N+3	CRC 3
3.N+4 … 4.N+3	4th part : XOR part
4.N+4	CRC 4

4.3 Network ID :

The goal of the network ID is to ignore radio frames which use the same NFPR protocol, the same frequency and the same modulation, but which do not belong to the same network (1 network is defined with 1 master and 1 or several clients). This is useful in case of cohabitation of several NFPR network on the same frequency in a geographic area.
This is the equivalent of CTCSS used on FM voice repeaters.
The Network ID value sent on radio is not directly the one selected by the user, but uses the transfer table below instead. The goal is to "whiten" the network ID value.
Remark: with integrated radio chips (like SI463), this byte is considered to be part of the sync word.

Value selected by user	Value sent inside radio frame	SI4463 API value
0	0xCC	0x33
1	0x6C	0x36
2	0x9C	0x39
3	0x3C	0x3c
4	0xC6	0x63
5	0x66	0x66
6	0x96	0x69
7	0x36	0x6c
8	0xC9	0x93
9	0x69	0x96
10	0x99	0x99
11	0x39	0x9c
12	0xC3	0xc3
13	0x63	0xc6
14	0x93	0xc9
15	0x33	0xcc

4.4 Radio frame length

Radio frames length are variable.
The length field is only 1 byte. It does not represent directly the lenght of radio frame. The number of bytes inside the radio frame after the "length field" is equal to :

Length field + 90

If upper layer wants to transport fewer bytes than minimum length, then the L2 layer will add "stuffing bytes" at the end. The L2 radio layer is not responsible of retrieving the original length of data if less than minimum length. The upper layer will receive data with stuffing bytes, and should adapt to that.

	Mini	Maxi	Maxi x6	Maxi x8
TX_size	94	346	2076	2768
Length field value	3	255		
Number of bytes after 'length field'	93	345	2070	2760
Data size with FEC	92	344	2064	2752
Data size without FEC	66	255	1530	2040
Raw data size if segmented	63	252	1512	2016

4.5 TDMA Byte

The TDMA byte is different between downlink radio frames (transmitted by Master) and uplink radio frames (transmitted by Clients).

<table>
<tr><th>Position</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td rowspan="2">Content</td><td rowspan="2">Parity Bit</td><td rowspan="2">Downlink/ uplink flag</td><td rowspan="2">TOP Synchro</td><td colspan="5">Downlink frames :
TDMA multi frame counter</td></tr>
<tr><td colspan="5">Uplink frames :
Uplink Buffer state</td></tr>
</table>

- Downlink/uplink flag :
  - Value = 1 for downlink radio frames
    A Client only accepts radio frames with 'downlink/uplink flag' = 1.
  - Value = 0 for uplink radio frames
    A Master only accepts radio frames with 'downlink/uplink flag' = 0.
- TOP Synchro:
  is set to 1 for the first radio frame inside one timeslot, either by the Master or one Client. The goal is to identify the timing, and synchronize without errors even if radio frames are lost
  - Clients use the first frame sent by Master as a timing reference for the new TDMA frame
  - The Master use this first frame sent by each client in order to measure the Timing Advance of each client.
- TDMA multi frame counter (downlink radio frames only) :
  Unsigned number.
  It counts the TDMA frame within a 32x TDMA multiframe. Used to identify which TDMA multiframe is currently active. The Master increments this counter by 1 at the beginning of each new TDMA frames.
- Uplink Buffer State (uplink radio frames only):
  Unsigned number.
  The goal is for each client to inform the TDMA master of its uplink bandwidth requirement. It must be sent within each uplink radio frame.
  The number represents approximately the number of micro slots (1 micro slot = maximum possible radio frame duration) required to empty the uplink buffer.
  The uplink buffer is the sum of both
  - IPv4 frames (0x02)
  - Signaling frames (0x1E)

4.6 Client ID:

Position	7	6	5	4	3	2	1	0
Content	Parity bit	Client ID						

Possible values for client ID:

- Client ID = 0x00 to 0x06. Seven values for identifying already connected clients.
- Client ID = 0x7E for "discovery" frames (from clients not yet connected)
- Client ID = 0x7F for "broadcast" frames

The meaning of the 'Client ID' field is different between uplink and downlink frame.

- Downlink frames: the goal is to identify the destination and therefore for the client to filter radio frames.
- Uplink frames: the goal is for the Master to identify the sender of each frame (which client)

	Client ID Field possible value		
Protocol Type	**For downlink radio frames**	**For uplink radio frames Client already connected**	**For uplink radio frames Client not connected**
0x00 = NULL	(Not applicable)	Source client address	(Not applicable)
0x02 = IPv4	Destination client address (or 0x7F broadcast in the future, not implemented yet)	Source client address	Not allowed.
0x1E = Signaling	0x7F = Broadcast	Source client address	0x7E (for discovery frames)
0x1F = TDMA allocation	0x7F = Broadcast	(Not applicable)	(Not applicable)

Each modem must filter the radio frames that it receives, according to the following rules

- A Master accepts only uplink radio frames with following client ID
  - Client ID corresponding to an already connected client
  - 0x7E for discovery
- A Client accepts only downlink radio frames with the following client ID:
  - It's own client ID
  - 0x7F for broadcast frames

4.7 Segmenter byte:

The segmenter byte is optional; it is currently only used by IPv4 protocol.
In the following paragraph, "packet" means the raw data structure which is bigger than what we can transport inside one single radio frame. This "packet" is an IPv4 packet.

Position	7	6	5	4	3	2	1	0
Content	Packet counter				Last Segment	Segment counter		

- Packet counter: counts the packets. Helps the receiver to identify which segments belong to the same packet.
  Increments by 1 for each new packet (segmented or not); this counter loops: the packet counter value after 0xF is 0x0.
- Last segment: Set to 1 if the current segment is the last segment of data of the current packet. Otherwise set to 0 if there are more segments to come.
- Segment counter: segment numbering within one packet. Starts from Zero, and increments by 1 for each following segment.
  If the receiver reads not contiguous segment counter within the same packet, it should reject all the frames of the packet.

Once segmented, every segment is carried inside one separated radio frame, with its own header and its own FEC.
Segments should be transmitted in the right order, from first to last (there is no reordering mechanism), but they can be transmitted in a non-contiguous manner, especially if higher priority radio frames have to be transmitted in between.
The total unsegmented length of data carried cannot be above 2016 bytes, which correspond to 8 radio frames.

4.8 Protocol Byte

Below is a list of all protocols which can be carried inside a radio frame.

Protocol ID	**Description**	**Use of segmentation**	**Valid for…**	
			Downlink	**Uplink**
0x00	<u>Null frame</u> (ignore) Used (only at uplink) in cases where a frame should be sent, to maintain the synchronisation and Timing Advance measurement, even if there is no data.	NO	NO	YES
0x02	IPv4	YES	YES	YES
0x1E	Signalling	NO	YES	YES
0x1F	TDMA allocation	NO	YES	NO

5 Managed TDMA

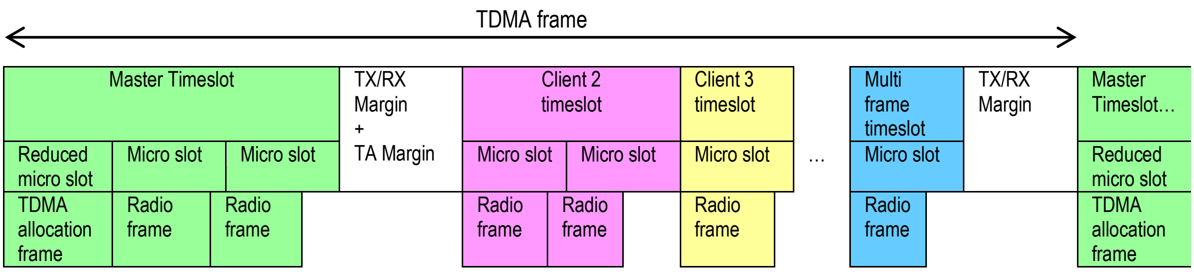
5.1 TDMA – general principle, and TDMA frame structure

The TDMA mechanism distributes timeslots equitably between every modem, considering the needs expressed by all modems (Master or Client).
The Master transmits allocation information to all clients inside a TDMA allocation radio frame, sent at the very beginning of each TDMA frame.
This allocation is adjusted automatically by the Master in real time.
The uplink/downlink ratio is therefore adjusted automatically in real time.

The TDMA frame is the shortest repetitive period where one or several radio stations (Master and Clients) transmit information
Each TDMA frame is split into several time slots. Within each time slot, only one radio station is allowed to transmit.

The total duration of the TDMA frame is frozen by design, and depends on the modulation selected.
This duration corresponds to the sum of:

- 1 reduced micro slot, for the TDMA allocation frame (plus inter-frame margin)
- 17x micro slots.
  The duration of these micro-slots is the maximum duration of a radio frame (plus inter-frame margin)
  Remark: The very last micro slot is dedicated to "8x multi frames".
- 2x TX-RX switch margin
  - one for transition between downlink and uplink
  - one for transition between uplink and downlink
- 1x Timing Advance Margin. It corresponds to the maximum propagation delay accepted (2ms round trip, or 300km).



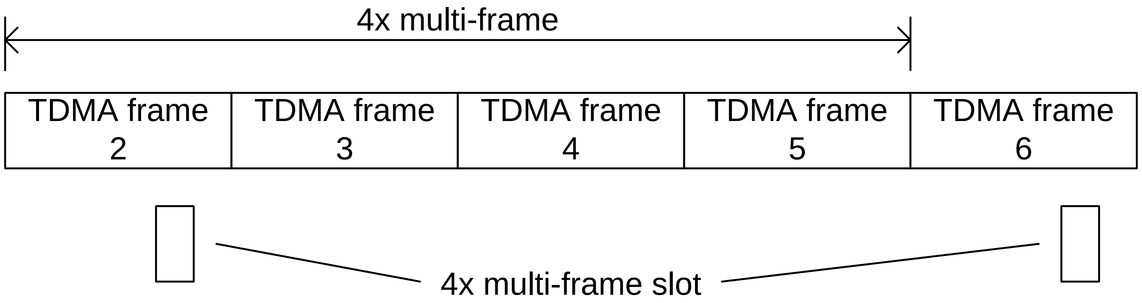
Warning: the timing diagram shown above is represented from the Master point of view. Due to propagation delay, it is different at client side: client transmissions are anticipated with the "Timing Advance" mechanism.

Rules (for both Master and Clients):

- The duration of one timeslot is a multiple of the duration of the duration of micro slots (except for the Master, which timeslot integrates a 'reduced micro slot' dedicated to TDMA allocation frame)
- All the frames sent by one modem must be strictly inside the allocated timeslot.
- The first radio frame within one timeslot must be sent at the exact beginning of the timeslot
- The following radio frames within one timeslot (if further frames) must be sent immediately after the end of the previous radio frames.
- The radio frames may be shorter than one micro slot, because
  - Because the preamble can be shorter than the longest one
  - Because the data field of the frame can be shorter than the maximum allowed
- Therefore, except for the very first radio frame of one timeslot, following radio frames don't have to be aligned with micro slots.
- One modem can stop its transmission before the end of its timeslot (if it does not require the whole timeslot).

5.2 TDMA multi frame

General principle:



The concept of multi frame is used to transmit data with higher period than the TDMA frame period. It also defines a repetitive period.
A multi frame period is several times the TDMA frame duration.
There are 5 types of multi-frames:

- 2x multi-frame
- 4x multi-frame
- 8x multi-frame
- 16x multi-frame
- 32x multi-frame

Specific multi-frame-slots are defined inside a TDMA frame. These are only used for uplink of clients which do not need lot of bandwidth.
The duration of these timeslot is always 1 micro slot.
One mutli frame timeslot is identified with 3 characteristics

- The multi-frame period: 2x, 4x, 8x, 16x or 32x.
- The multi frame offset: this is the "TDMA frame counter" of the first frame which contains this slot, within a 32x frame number. On the above example, the multi frame offset of this slot is 2. It is interpreted with the "TDMA multi frame counter" sent by Master.
- The offset inside a TDMA (single) frame.

A TDMA frame counter is sent by the master inside the TDMA byte of each of his radio frame. With the help of the multi frame period and the offset, it allows to identify to which TDMA frames corresponds one specific multi-frame slot.

Multi-frame usage

Currently, even if the protocol enables lots of configurations for multi frame, the Master allocates multi-frames in a static manner.

Currently, there is one single timeslot inside each TDMA frame, dedicated to a single TDMA-multi-frame timeslot.

There is currently 1 series of 8x multi-frames, at the very last timeslot of each TDMA frame, which are allocated this way:

- Multi-frame Offset 0 to 6: 7 static slots, one for each client. These slots are used when the Master allocates "slow mode" to that client.
- Multi frame offset 7: specific static slot for "discovery" of new clients. It is allocated to 'client ID = 0x7E' (not connected clients).

5.3 Fast / slow client

Each client is put by the Master in either Fast or Slow mode, depending on its uplink needs.

- In Fast mode, the Master allocates dedicated timeslots in each TDMA frame; therefore uplink transmission for this client can occur often.
- In Slow mode, the Master allocates only one timeslot inside the 8x TDMA multi frame; therefore uplink transmission for this client occurs 8 times less often. It is used to maintain synchronization and connection for clients who need only small amount of uplink.

The Master determines if one client is in Fast mode or not with the following rule:

- If the client announces uplink needs less or equal to '1 microslot', for the 32 previous TDMA frames, then the client is forced to Slow mode. This rule is true even if the client is already in 'slow mode' and only transmits its uplink status once every 8 TDMA frame.
- Otherwise, the client is forced to Fast mode, at the beginning of next TDMA frame.

The timing advance is also computed and integrated to the timing offset, for Slow clients.

5.4 TDMA allocation frame

The TDMA master sends periodically, at the very beginning of each TDMA frame, a TDMA allocation frame (which is a radio frames) to all the clients.

Each TDMA allocation frame contains TDMA allocation characteristics for

- All connected client.
- Discovery slot (client ID 0x7E)

The radio frame structure is the standard structure, without segmentation byte.

The protocol ID is 0x1F.

The client ID address of the radio frame is 0x7F, which means “broadcast”.

The structure of the data field is described below:

Position (byte)		content	
1		Sync word	
2		Sync word	
3	Header	Network ID	
4		Length	
5		TDMA Byte	
6		Client ID	0x7F (broadcast)
7		Protocol	0x1F
9	First client allocation (5 bytes)	Client ID	
10		Time offset LSB	
11		Time offset MSB	
12		Bits 7..4 : Uplink power Bits 3..0 : Slot length	
13		Bits 7..4 : multi frame period Bits 3..0 : multi frame offset	
14	2nd client allocation (5 bytes)	Client ID	
…		…	
18		Bits 7..4 : multi frame period Bits 3..0 : multi frame offset	
…	…	…	
N		STOP	0xFF
…		Stuffing bytes (if necessary)	

Definition of parameters:

- multi frame period

value	Signification
0	Basic TDMA frame
1	x2 multi frame
2	x4 multi frame
3	x8 multi frame
4	x16 multi frame
5	x32 multi frame

- Time offset.
  Unsigned number; Resolution: 10 µs.
  It defines the timing offset at which the client should start transmission.
  T0 is the sync byte of the downlink sync radio frame.
  It includes the offset of the slot and the timing advance computed by the Master (or zero for discovery slot).
- Multi frame offset :
  Unit/increment: one TDMA frame.
- Uplink power: Currently not used, not yet implemented.
- Slot length: Unsigned number. Resolution: 1 micro slot (= maximum radio frame duration).

5.5 TDMA allocation strategy (Fast clients only)

This chapter describes how the Master allocates the timeslots for itself and for all connected clients with "Fast" status.

<u>Modems requests gathering:</u>

The Master collects all the needs/requests of each modem (including itself) with the following information:

- For itself : its downlink buffer filling (number of microslot needed to empty its downlink buffer, including signaling and IPv4 radio frames)
- For each client:
  - If one valid TDMA byte was received recently (within the previous TDMA frame) from this client, the need is directly the last valid value of "uplink buffer state".
  - If no valid TDMA byte was received recently from this client, the Master takes the last valid "uplink buffer state" value from this client, decremented by one after each TDMA frame period

<u>Micro time slot distribution:</u>

- First, the Master allocates one reduced micro slot for itself, for the TDMA allocation frame
- Then the Master distributes the 16 micro slots among itself and all connected clients with the following rules
  - Each modem must have at least one micro slot allocated (zero micro slot is not allowed), even if the need is zero
  - The Master distributes the micro slots equitably regarding the need collected for each modems (Master or client), using a round-robin mechanism.
  - The weight for the Master is artificially doubled in case more than one "fast" client is connected.
  - If all needs collected are fulfilled, and there are still unused micro slots left, then the Master distributes the remaining micro slots equally to itself and to fast clients. All micro slots must be allocated.
- The 17th micro slot is dedicated to 8x multi frames

Allocation announcement

The Master announces its TDMA allocation decision, with the previous information, inside one TDMA allocation radio frame.

The following rules apply:

- Refer to timing diagram at beginning of “Managed TDMA” chapter to understand where margin (TA margin and TX/RX margin) are taken into account
- If one modem has an allocation of more than one microslot, then these microslots must be contiguous, in order to form a single timeslot.
- The Master has always the first timeslot of one TDMA frame
- The 8x Multi frame slot is always the last timeslot inside one TDMA frame.

5.6 Client behaviour regarding TDMA allocation

Every client modem must send at least one radio frame, inside each of its timeslots (Fast or Slow), in order to maintain synchronisation and Timing Advance computation. If one client modem does not have any data in its uplink buffer, then it sends a NULL frame (with whatever content inside).

If one client loses either the “top synchro” from the Master, or loses the content of the TDMA allocation frame for this specific TDMA frame (because of radio interference for example), then it is allowed to use:

- The “TOP synchro” from previous TDMA frame, plus its knowledge of the duration of a TDMA frame (according to annex 1)
- And/or the “TDMA allocation” from previous TDMA frame. This can induce radio frame collisions, but it is often more useful than harmful.

5.7 Synchronisation and Timing Advance

All timings are computed by Master and Clients with the help of the following rules:

- At reception, a modem determines the beginning of the transmission of a timeslot : the moment of a sync word of a frame with 'TOP Synchro = 1', minus the maximum preamble duration
- At transmission: The transmission moment is the beginning of transmission of the preamble of the frame.

The Master computes the "Timing Advance" needed for each connected client. This "timing advance" is the sum of propagation delay at both uplink and downlink, due to distance between Master and Client. The Client must anticipate its transmission by this "Timing advance". The Master computes the timing advance of one client with the help of

- The previously requested time offset for this client inside TDMA allocation frame
- The measured offset at reception of the first radio frame of the client inside the TDMA frame (identified with TOP synchro bit).

By design, the maximum allowed Timing Advance is 2ms, equivalent to 300km.

The timing advance is then integrated (subtracted) to the timing offset sent inside the next TDMA allocation frame for this specific client.

<u>Discovery slot</u>

Discovery radio frames are signalling radio frames sent by not-connected clients, which request connexion. These radio frames are sent with client ID = 0x7E. The TDMA allocation for this "discovery slot" is established with Timing Advance equal to zero, because the timing advance is unknown. These discovery radio frames are short enough (they only contain one signalling connection request); therefore they will not overlap the next slot, whatever the propagation delay (0 to 2ms).

6 Signalling

6.1 Signalling – general information

Signalling radio frames must have higher priority than IPv4 frames, in order to maintain the signalling mechanism, whatever the IPv4 buffer congestion state.
Signalling frames are identified with protocol_ID = 0x1E.
These frames are not segmented (no segmenter byte).
The data field of the radio frame contains a TLV (type, length, value) structure.
This TLV structure allows the transport of several ‘signalling messages’ inside one single radio frame.
The length of a ‘signalling message’ is considered without type byte and without length byte.
At downlink side, all signalling radio frames are “broadcast”, and must be interpreted by all clients.
One single signalling radio frame can contain several signalling messages dedicated to different purposes, and/or to different clients. There is no relation between 2 consecutive signalling messages inside one single signalling radio frame. Each signalling message must be interpreted independently.

A signalling type 0xFF, length 0, is put at the end of the TLV structure of a signalling frame, in order to identify the end of the useful data inside the radio frame.

If one modem wants to send more signalling messages than one single radio frames can carry, then it must split the signalling data into several signalling radio frames, each one having its own TLV structure, without splitting one signalling message in the middle.

<table>
<tr><td>Position (byte)</td><td></td><td>content</td><td>Value</td></tr>
<tr><td>1</td><td></td><td>Sync word</td><td></td></tr>
<tr><td>2</td><td></td><td>Sync word</td><td></td></tr>
<tr><td>3</td><td rowspan="5">Header</td><td>Network ID</td><td></td></tr>
<tr><td>4</td><td>Length</td><td></td></tr>
<tr><td>5</td><td>TDMA Byte</td><td></td></tr>
<tr><td>6</td><td>Client ID</td><td></td></tr>
<tr><td>7</td><td>Protocol</td><td>0x1E</td></tr>
<tr><td>9</td><td rowspan="5">First signalling message</td><td>Signalling message 1 Type</td><td></td></tr>
<tr><td>10</td><td>Signalling message 1 Length</td><td></td></tr>
<tr><td>11</td><td rowspan="3">Signalling message 1 content</td><td rowspan="3"></td></tr>
<tr><td>…</td></tr>
<tr><td>10+size</td></tr>
<tr><td></td><td rowspan="5">2nd signalling message</td><td>Signalling message 2 Type</td><td></td></tr>
<tr><td></td><td>Signalling message 2 Length</td><td></td></tr>
<tr><td></td><td rowspan="3">Signalling message 2 content</td><td rowspan="3"></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td></td><td rowspan="2">END field</td><td>End signalling message type</td><td>0xFF</td></tr>
<tr><td></td><td>End signalling message length</td><td>0x00</td></tr>
</table>

6.2 List of signalling messages types and their content:

Signalling message type	Signalling message Label	Can be sent by…		Signalling message Length	Data position (bytes)	Data length (bytes)	Data content
		Master	Client				
0x01	WHO	YES	YES	30	1	1	Client ID
					2..17	16	Callsign
					18..21	4	Start IP
					22..25	4	Number of IPs
					26	1	RSSI (received power)
					27..28	2	BER (error rate)
					29..30	2	TA (timing advance)
0x05	Connection request	-	YES	21	1..16	16	Callsign
					17..20	4	Nb of IP requested
					21	1	Static IP requested (not yet implemented)
0x06	Connexion ACK	YES	-	59	1	1	Client ID
					2..17	16	Client Callsign
					18..21	4	Start IP
					22..25	4	Number of IPs
					26..41	16	Master Callsign
					42..45	4	Modem IP
					46..49	4	IP Subnet Mask
					50	1	Default route activation
					51..54	4	Default route value
					55	1	DNS server activation
					56..59	4	DNS server value
0x07	NACK new connexion	YES	-	33	1..16	16	Client Callsign
					17	1	Reason of NACK
					18..33	16	Master Callsign
0x0B	Disconnect request	-	YES	17	1	1	Client ID
					2..17	16	Client Callsign
0x0C	Disconnect ACK	YES	-	17	1	1	Client ID
					2..17	16	Client Callsign
0xFF	END	YES	YES	0	-	-	-

Data content

- Reason of NACK : 2 possible values
  - 0x02 : Not enough free IPs
  - 0x03 : Maximum number of client reached
- Callsign: this field is 16 bytes, made of the following data:
  - First 2 random bytes that are generated once and stored in non-volatile memory by the modem. The goal is to accept errors in the NPR network configuration, with several modems having the same 'callsign'.
    Remark: in NPR70 modem v02, these 2 random bytes are also used for the last 2 bytes of the local Ethernet-MAC address.
  - Then the callsign itsel, which is a character chain, maximum size 13 characters.
  - Last byte is always zero
- All IP addresses (or IP ranges sizes or IP subnet mask): 4 bytes represented the raw IP address like inside IP packets.
- TA – Timing Advance: 2 bytes signed number (short int).
  Represents the timing advance measured by Master for one client.
  Resolution: 1 microsecond.
  You should multiply this value by 0.15km in order display an estimation of distance between master and client.
- RSSI : offseted Received Signal Strength Indicator; unit: dB.
- 'DNS server' or 'Default route' activation state:
  - 0x00 : not activated
  - 0x01 : activated

6.3 Who

Each modem must send 'who signalling messages' every 2 seconds (in order to comply with amateur-radio regulations).

- A client must send who signalling messages only when it is in 'connected' state; It must send who signalling information about
  - About itself
  - About the master it is connected to
- The Master must send 'who signalling messages', inside a 'broadcast radio frame', about
  - About itself
  - About all the clients considered with 'connected' state

The meaning of several fields inside who signalling messages vary according to the following table

	Who sent by Master about…		**Who sent by a Client about…**	
	… about itself	**… about client**	**… about itself**	**… about Master**
Start IP	Zero	Start IP	Start IP	Zero
Number of IP	Zero	Nb of IP	Nb of IP	Zero
RSSI	Zero	RSSI of uplink about this client	RSSI of downlink	Zero
BER	Zero	BER of uplink about this client	BER of downlink	Zero
TA Timing Advance	Zero	TA estimation	Zero	Zero

6.4 Connection / disconnection mechanism

Behaviour at client side:

A client must send Connection request signalling messages in the following situations:

- Client not connected, but trying to connect : once every 6 seconds
  The instant of transmission of the radio frame containing this "connection request" depends on wether
    - If the (not yet connected) client gets valid downlink signals, valid TDMA allocation, and valid TDMA synchro, then it must send the radio frame inside the next "discovery slot", defined by TDMA allocation for client=0x7E.
    - If the (not yet connected) client does not get either valid downlink signal or valid TDMA allocation or valid TDMA synchro, then it must send this radio frame "whenever it wants", as soon as possible. If the radio link is OK, the Master will wake-up automatically from 'Standby Mode' after reception of this frame.

- Client not connected, with 'connection rejected' state: once every 30 seconds.
- Client with connected state:
    - Normally once every 10 seconds. This is necessary in order for the Master to maintain the client at "connected state".
    - Once every 2 seconds it the client has not received a 'connection ACK' to its previous request.

A client with status 'connected', which does not receive 'connection ACK' for itself for 20 seconds (whatever the reason), must switch its status to 'not connected, trying to connect'.

Behaviour at Master side:

The Master must answer as soon as possible to connection requests

The answer can be:

Request (from Client to Master)	**Answer (from Master to Client)**
0x05 Connection request	0x06 Connection ACK
	0x07 Connection NACK
0x0B Disconnection Request	0x0C Disconnect ACK

If one client is already considered with "connected" status by Master, then the Master must answer to the request with exactly the same content (ACK, Start IP, etc…) than previously.

If the Master does not receive any request from one already connected client for 20 seconds (timeout) then it must consider this client disconnected, without sending any signalling message. This occurs when the modem is suddenly shut off or when the radio link is broken.

7 Master standby mode

The Master must enter 'standby mode' if it does not receive any radio frame for 30 seconds.
The Master must leave standby mode and go back to "normal mode" immediately after reception of a radio frame.
The radio frames which trigger exit from standby mode can contain errors (either FEC or parity bit), in order to wake-up the Master as soon as possible even if the radio link is poor (antenna not well pointed at client side).

Master behaviour in the 2 modes:

- Standby mode: the Master just listens to radio frames.
- Normal mode : the Master computes the TDMA allocation, sends radio frames in each of its timeslot in each TDMA frame, according to the TDMA mechanism

8 IPv4 transport

8.1 IPv4 data encapsulation

IPv4 packets are transported inside specific radio frames using

- MTU 1500
- Protocol ID : 0x02
- NPR Segmentation mechanism

8.2 IPv4 Routing

Currently NPR protocol can only transport 'unicast IPv4 packets'.
(Future evolution possible for Multicast…).

<u>Client behaviour:</u>
One client sends to the radio unicast IPv4 packet which destination IP address

- Either belong to the subnet or not
- And do not belong to the IPv4 address range allocated to this client
- And is not the modem IP address

<u>Master:</u>
The Master sends to the radio unicast IPv4 packets which destination IP address

- Belong to the subnet
- And belong to IP range of clients with the status "connected"

The master discards IPv4 packets which destination IP address is inside the NPR IP range, but not allocated to any client.

9 Annex 1 : timing parameters

Modulation / Timing parameter	24 500kSps 4GMSK 1Mbps	14 500kSps 2GMSK 500kbps	23 300kSps 4GMSK 600kbps	13 300kSps 2GMSK 300kbps	22 180kSps 4GMSK 360kbps
TDMA frame duration	81 300	130 000	117 000	197 000	176 000
x8 multi frame duration	650 400	1 040 000	936 000	1 576 000	1 408 000
microslot duration (without interslot margin)	4 060	6 840	6 090	10 720	9 480
reduced microslot duration (without interslot margin)	2 210	3130	3 000	4 540	4 330
Interslot margin	300	300	300	300	300
Maximum preamble size	60 bytes	60 bytes	42 bytes	42 bytes	32 bytes
Minimum preamble size	16 bytes	16 bytes	16 bytes	16 bytes	16 bytes
TX/RX margin	1 300	1 300	1 300	1 300	1 300
TA (Timing Advance) Margin	2 000	2 000	2 000	2 000	2 000

All timings are in micro seconds.