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Radio Link Specification for RTI-driven Traffic Light Priority and Display Cleardown

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1 Introduction

1.1 Introduction and Scope

1.1.1 This document details the specification and methodology for the transmission of data from public service vehicles, such as buses and trams, to traffic signals and electronic public transport real time information displays.

1.1.2 This mechanism allows vehicles that are running behind schedule to request priority from traffic signals, and allows vehicles that are leaving bus stops to clear the related information from the display in a timely fashion.

1.1.3 This document specifies:

- the message envelope;
- transmission strategy;
- message content;
- the electrical characteristics of the transmitter and receiver.

1.1.4 It is intended to provide all necessary information to allow equipment from different suppliers to interoperate, to the extent that vehicles fitted with equipment from one supplier communicate with equipment from another supplier's system.

1.1.5 Un-acknowledged transmissions are used, so that vehicles only need to be fitted with transmitters and traffic lights and RTPI displays only need to be fitted with receivers. Spectrum usage and the potential for contention can be calculated based on fixed and known parameters.

1.1.6 Version 1.6 of this specification introduced an option for a type 3 message which enhances type 1 to allow for an increased number of trigger points.

1.1.7 All messages consist of a single data packet with a six-byte payload, or in the case of type 3 message seven-bytes.

1.1.8 There are currently three defined message types, and five additional message types that are reserved for future expansion.

1.1.9 This document does not cover the physical attributes of any equipment.

1.1.10 It does not cover the methodology for determining where the trigger points are positioned, or what strategy a traffic signal should use in response to a request.

1.1.11 It is incumbent on manufactures to ensure their solutions meet all necessary system requirements.

2 Spectrum and Ofcom Guidelines

2.1 Ofcom (previously the UK Radiocommunications Agency) has made available a channel for this application throughout the UK, excluding Northern Ireland 188.175 MHz. The paired frequency associated with this channel is 180.175MHz.

2.2 180.175MHz is reserved

2.3 Note also that even though this frequency has been reserved for this application, each individual local authority, PTE or bus operator intending to utilize this frequency must apply to Ofcom for a license before using this frequency in any particular area.

3 Transmission of the Data

3.1 Message envelope

3.1.1 The six bytes of message content combine with five bytes of overhead to form an eleven byte message over air. The encoding mechanism is based on that is based on MPT1317 section 4 – Recommended Digital Code Format, which defines the use of a pure bit stream with no start or stop bits. Not all values are as specified in the MPT1317 Protocol, and a number of changes have been made.

3.1.2 The departures from the MPT1317 standard are as follows:

- The preamble has been shortened from 16 bits to 8 bits. A 16-bit preamble may still be used as long as the message length, including key-up and key-down time, is less than 50 ms.
- No address field is used, the Sync is followed immediately by a data word, as indicated by the 0 in D7 of byte 0 of the message content. This encoding method should ensure that communications on this channel are never misinterpreted by MPT1317 and MPT1327 radios erroneously on this channel that are expecting standard MPT1317 messages.
- The transmission speed is 2400 baud using 1200Hz and 2400Hz tones instead of 1200 baud with 1200Hz and 1800Hz tones. This is however a recognised extension on MPT1317.
- The message structure consists of an 8-bit pre-amble, a 16-bit synchronisation word, a 48-bit data packet and a 16-bit CRC. The table below is a summary of this structure.

Description	Length	Contents	Notes
Pre-amble	8 bits	Bit reversals	10101010 (Binary)
Sync	16 bits	EB23 (Hex)	The suggested synchronisation codeword is 'SYND'. This is used for 'Traffic' channel data codewords.
DATA	48 bits or 56 bits	TLP or Clear	Free format data – the 6 bytes available for transmission to either the traffic controller or bus stop display. Bit reversals or encoding methodologies are not required here. Type 3 messages are 7 bytes in length.
Check bits	16 bits	See 7.2	A 15-bit CRC with an inverted 15th bit to check for framing errors. Followed by an even parity bit. The entire 16 bits are then inverted.

3.2 Calculation of Check Bits

3.2.1 The mechanism used to calculate the check bits is identical to the MPT1317 method (section 4.1.4). Note that in this document bits are numbered from 0 whereas in MPT1317 they are numbered from 1.

3.2.2 The sixteen Check bits are calculated in four steps:

- fifteen check bits are appended to the 48 data bits by encoding them in a (63, 48) cyclic code. For encoding, the information bits 1 to 48 may be considered to be the coefficients of a polynomial having terms from x62 down to x15. This polynomial is divided, modulo 2, by the generating polynomial:

  x15+x14+x13+x11+x4+x2+1

- The fifteen check bits, i.e. code word bits 48 to 62, correspond to the coefficients of the terms from x14 to x0 in the remainder polynomial found at the completion of the division. The (63,48) cyclic code has a minimum distance of 5 and so guarantees detection of up to 4 bit errors in one code word.
- The final check bit of the (63,48) cyclic code (code word bit 62) is inverted to protect against framing errors in the decoder.

- One bit is appended to the 63 bit block to provide an even bit parity check of the whole 64 bit codeword. The overall parity bit ensures that all odd numbers of errors can be detected, so the overall 64 bit code guarantees that up to 5 bit errors can be detected.
- The entire sixteen bits are then inverted.

3.2.3 At the receiver, each code word may be checked for errors by recalculating the check bits for the received information bits. Any differences between the received check bits and the recalculated check bits indicate that the received code word contains errors and that the message should be discarded. Receivers may, if they wish, attempt to perform error correction on code words found to be in error. If the code work is able to be corrected then it need not be discarded and may be 'received' as if there had been no error in the first place. (See Appendix 2 of MPT1327 for more information on possible corrections.

3.2.4 For the test case of the following six bytes of data 0x12, 0x34, 0x56, 0x78, 0x90, 0x12 the sixteen check bits will be 0x52, 0xFC.

3.3 Bit Ordering

3.3.1 In line with MPT1317, the over-air transmission will be most significant bit transmitted first.

3.3.2 Transmission will therefore be in the following order with bit 1 being the first to be transmitted and bit 88 the final bit.

3.3.3 Preamble

Bit Position	1	2	3	4	5	6	7	8
Value	1	0	1	0	1	0	1	0

3.3.4 SYND

Bit Position	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Value	1	1	1	0	1	0	1	1	0	0	1	0	0	0	1	1

3.3.5 Data – see section 4 for details of data bytes content

Byte 0			
Bit Position	25	…..	32
Content	MSBit always 0	…..	LSBit

Byte 1			
Bit Position	33	…..	40
Content	MSBit	…..	LSBit

Byte 2			
Bit Position	41	…..	48
Content	MSBit	…..	LSBit

Byte 3			
Bit Position	49	…..	56
Content	MSBit	…..	LSBit

Byte 4			
Bit Position	57	…..	64
Content	MSBit	…..	LSBit

Byte 5			
Bit Position	65	…..	72
Content	MSBit	…..	LSBit

CRC				
Bit Position	73	…..	87	88
Content	Polynomial Part			Parity Part
	16 bits calculated as per section 3.2			

3.3.6 Where a Type 3 message is being sent the data bits will be:

Byte 0			
Bit Position	25	…..	32
Content	MSBit always 0	…..	LSBit

Byte 1			
Bit Position	33	…..	40
Content	MSBit	…..	LSBit

Byte 2			
Bit Position	41	…..	48
Content	MSBit	…..	LSBit

Byte 3			
Bit Position	49	…..	56
Content	MSBit	…..	LSBit

Byte 4			
Bit Position	57	…..	64
Content	MSBit	…..	LSBit

Byte 5			
Bit Position	65	…..	72
Content	MSBit	…..	LSBit

Byte 6			
Bit Position	73	…..	80
Content	MSBit	…..	LSBit

CRC				
Bit Position	81	…..	94	95
Content	Polynomial Part			Parity Part
	16 bits calculated as per section 3.2			

3.4 Modulation Specification

3.4.1 The modulation method is sub-carrier modulation using FFSK:

Bit Rate	2400bit/s
Modulation Rate	2400 baud
Binary '0'	2400Hz
Binary '1'	1200Hz

3.4.2 Based on the message length of 88 bits including 8 bits of preamble, (See section 3.1) the data will take 36.6 ms to transmit.

3.4.3 Added to this should be the key-up and key down times detailed below.

3.5 Message Transmission Duration

3.5.1 The transmitted message shall have a duration of less than 50 ms, including the maximum allowable key up and key down times.

3.6 Transmitter specification

3.6.1 Minimum power (ERP): 50 mW

3.6.2 Maximum power (ERP): 1000 mW

3.6.3 Recommended power (ERP): 500 mW

3.6.4 The transmitter shall conform to one of the following standards, EN330-220 or EN300-113 with the additional conditions as detailed below.

3.6.5 Note that the maximum permitted power using EN300-220 is 500 mW

3.6.6 Additional Conditions for EN300-220:

Adjacent Channel Power	Less than 1 µW
Transmitter rise and fall times	Less than 13.4 ms
Adjacent channel transient power	The transient power, in the adjacent channels shall not exceed a value of 50.0 dB below the carrier power (conducted) of the transmitter (in dBc) without the need to be below 2 µW (−27.0 dBm)

3.2 Additional Conditions for EN300-113 :

Transmitter rise and fall times combined	Less than 13.4 ms

3.7 Receiver Specification

3.7.1 Receivers shall conform to either EN300-220 or to EN300-113, however they must also comply with the additional conditions detailed below.

3.7.2 Additional Conditions for EN300-220:

Receiver co-channel rejection at 10^{-5} BER	<20 dBc
Maximum usable sensitivity	The value mentioned, 6 dBµV, is mandatory, not just for guidance.
Adjacent Channel Selectivity	The value specified, 60 dB, is mandatory, not just for guidance.
Spurious Response Rejection	The value specified, 70 dB, is mandatory, not just for guidance.
Intermodulation Response Rejection	The value specified, 65 dB, is mandatory, not just for guidance.

Blocking and Desensitisation	84 dB is required.

3.7.3 Additional Conditions for EN300-113 :

Receiver co-channel rejection at 10^{-5} BER	<20 dBc

3.8 Message Timing

3.8.1 Vehicles can transmit messages to traffic signals at any time to request priority. However, to improve efficiency it is recommended that vehicles only transmit Traffic Light Priority Messages synchronised to a 50ms slotting system synchronised to UTC. These slots start at UTC midnight and every 50ms thereafter. UTC is obtained from GPS receivers.

3.8.2 The method of communication with signs is more complex. RTI Displays may be fitted with a radio receiver exclusively used for use on the RTIG frequency. However, the standard does allow a single radio to be used to receive both Clear-down messages on the RTIG frequency and data from a central system using time-multiplexing. To accommodate this time-multiplexing vehicle must only send Clear-down messages within defined periods of time, called Clear-down windows.

3.8.3 Clear-down windows are 200ms wide. They are synchronised to UTC and are timed to start at UTC midnight and every 4 seconds thereafter. A vehicle wishing to communicate with a RTI Display should select a random slot within the Clear-down Window for transmission. For preference Traffic Light Priority Messages should not be transmitted within this Clear-down Window.

3.8.4 A simple system which only implements Traffic Light Priority can therefore send messages at any time.

3.8.5 A more advanced system implementing Traffic Light Priority and Clear-down in the most efficient manner will implement both the slotting mechanism and the Clear-down window. All messages will be slotted, Clear-down messages will only be transmitted in Slots within the Clear-down Window, and all Traffic Light Priority Messages will be transmitted outside the Clear-down Window.

3.9 Slotting

3.9.1 Each second is divided into 20 slots, each of which being 50ms in length.

3.9.2 Slots are synchronised to the 1 pulse per second signal from the GPS receiver. The message content takes 36.6ms and the combined transmitter key-up and key-down time must be less than 13.4ms.

3.9.3 When slotted transmissions are being used the timing of message transmission should be arranged to ensure that the over-air transmission occurs within a single 50ms slot.

3.10 Clear-down Window

3.10.1 Clear-down Windows occur every 4 seconds and last for 200ms. They are synchronised to UTC starting with the rising edge of the 1 pulse per second signal from the GPS receiver.

3.10.2 The start of each Clear-down Windows occur, therefore at the following times: Midnight (00:00:00), 4 second past midnight (00:00:04), 8 second past midnight (00:00:08) and so on until (23:59:56).

3.10.3 When a slotting system is also use the Clear-down Window is divided into four Slots, each of 50ms.

3.11 Transmission and Re-Transmission

3.11.1 For any transmission on the RTIG channel there is a chance that the message will not be received due either to a collision with another message or due to interference from another source. In order to greatly increase the chance of correct reception it is recommended that a re-transmission scheme is used.

3.11.2 To achieve a high communications reliability the Traffic Light Priority Messages shall be transmitted a total of three times. These transmissions should occur within a 2 second period using the transmission strategy described above with a randomised delay between each transmission. When using the Slotting system this delay should be a multiple of 50ms.

3.11.3 To achieve a high communications reliability, the Clear-down messages should be transmitted twice, once in each of two successive Clear-down Windows.

4 Message Detail

4.1 Message types

4.1.1 Eight message types are available, of which only two are currently defined. The Message Type is encoded into bits 4, 5 & 6 of byte zero. Message type 1 is used for signalling priority request information to traffic signals. Message type 2 is used to communicate clear down information to real time information displays. Message types 0 and 3 to 7 are reserved

4.2 Traffic Light Priority Request (Message Type 1)

4.2.1 This message is used to request priority from traffic junctions.

4.2.2 Three Messages can be sent as the vehicle progresses through the junction:

- ‘registration’ at some distance indicates that a vehicle is approaching;
- ‘request’ request immediate priority;
- ‘clear’ indicates that the vehicles have cleared the junction;

4.2.3 For a simple implementation, only the ‘Request’ message is used.

4.2.4 The optional Registration message is used to give advanced warning that the vehicle is approaching the junction. It is sent on the early stages of the approach to the junction. No immediate changes to the signals would normally be initiated by this message.

4.2.5 The Request message indicates an immediate requirement for priority. The message is sent as the vehicle approaches the junction.

4.2.6 The optional Clear message is used to indicate that the vehicle has cleared the junction. This message would normally be transmitted on the exit from the junction.

4.2.7 Each of these messages also provides additional information indicating:

- which traffic signal the request is for;
- which movement through the junction is to be performed;
- which priority level is required;
- optionally which vehicle is requesting priority;
- optionally the deviation from schedule.

4.2.8 The table below names the fields, describes their contents, and gives their lengths in bits.

Field Name	Contents	FieldRef	Length (in bits)	Optional
Traffic Signal Number	0 to 16383	TSN	14	No
Movement Number	0 to 31	MN	5	No
Trigger Point	0 to 9	TP	5	No
Priority	0 to 3	P	2	No
Schedule Deviation	Coded deviation	SD	4	Yes
Local VCC	0 to 15	LVCC	4	Yes
Vehicle Number	0 to 8191	VN	13	Yes
Total			**44**	

4.2.9 The location of data within the message is defined in the table below. This indicates, for example, that the Priority bits are assigned to bits 0 and 1 of byte 1 of the message.

Byte\bit	D7 msb	D6	D5	D4	D3	D2	D1	D0 lsb
0 (first)	0	0	0	1	SD3	SD2	SD1	SD0
1	VNO	MN4	MN3	MN2	MN1	MN0	P1	P0
2	VN8	VN7	VN6	VN5	VN4	VN3	VN2	VN1
3	LVCC3	LVCC2	LVCC1	LVCC0	VN12	VN11	VN10	VN9
4	TSN5	TSN4	TSN3	TSN2	TSN1	TSN0	TP1	TP0
5	TSN13	TSN12	TSN11	TSN10	TSN9	TSN8	TSN7	TSN6

Traffic Signal Number [TSN0..13]

4.2.10 This contains a numeric identifier for the traffic signal, which should be unique within a 20 km radius of the relevant traffic signal. Care should be taken close to the boundary of a transport authority that the same number is not allocated within this range by a neighbouring authority.

Movement Number [MN0..4]

4.2.11 A number of 'movements' though each signal will be defined, from 0 to 29. These can be defined as a table for each junction, detailing the Movement Number that should be associated with each possible entry and exit combination. These thirty possibilities are enough for every possible pathway through a junction with six entrances and six exits.

4.2.12 Movement 30 is reserved.

4.2.13 Movement 31 can be used within the junction to request 'all red' for use by emergency vehicles.

Trigger Point [TP0..1]

4.2.14 There are three user trigger points, 0=Registration, 1=Request, 2=Clear. If only one trigger point is being used then 1 (request) should be used.

4.2.15 The enhanced message option includes the ability to have more than three trigger points, up to a maximum of nine for use where three is insufficient. A decision on message length should be made during a system design phase as the original and enhanced message options are incompatible.

4.2.16 Note that if there is a bus stop close to the junction, the vehicle may wish to send the Request message as it leaves the bus stop.

4.2.17 Trigger point 3 is reserved.

Priority [P0..1]

4.2.18 The priority is set to 1 to 3. Priority 1 is the lowest priority, and Priority 3 is the highest priority. The local transport authority may publish guidelines on how these priorities should be assigned. If only one priority level is used, the level 1 should be used.

4.2.19 Priority level 0 is reserved.

Schedule Deviation [SD0..3]

4.2.20 An optional schedule adherence value may be included in the message. A total of 16 different states can be sent, and the following look-up table should be used to convert actual lateness into a 4-bit number.

4.2.21 Note than an entry of 0 is used to signify that a schedule deviation is not supplied, and 8 is used for a vehicle where the schedule is supplied and between 59 seconds late and 59 seconds early (positive deviations indicate late vehicles, negative deviations indicate early vehicles). A Traffic Light Controller may use this information, if supplied, in addition to the priority message to determine how to respond suitably.

	Schedule Deviation in minutes	
Value	**From**	**To**
0	Schedule deviation not supplied	
1	>=1	<2
2	>=2	<3
3	>=3	<5
4	>=5	<7
5	>=7	<10
6	>=10	<15
7	>=15	
8	>-1	<1
9	<=-1	>-2
10	<=-2	>-3
11	<=-3	>-5
12	<=-5	>-7
13	<=-7	>-10
14	<=-10	>-15
15	<=-15	

Local Vehicle Control Centre [LVCC0..LVCC3]

4.2.22 The Local VCC and Vehicle Number are optional items, and should both be set to zero if vehicle information is not being provided.

4.2.23 The vehicle information must not be transmitted unless a Local VCC has been assigned to the RTI system by the local transport authority.

4.2.24 A Local VCC value of 1 should normally be assigned to the primary RTI system in an area.

4.2.25 A Local VCC value of 2 is reserved for National Express.

4.2.26 Other RTI Systems, which operate within the area and provide vehicle information, must be assigned a Local VCC by the Local Transport Authority.

4.2.27 If an RTI System operator has a fleet of more than 8190 vehicles then the operator will be allocated more than one Local VCC value.

4.2.28 Note that as an individual vehicle roams from area to area it will need to use the appropriate, and possibly different, LocalVCC within each area.

Vehicle Number [VN0..12]

4.2.29 A numeric identifier for the vehicle, these will be unique within a particular Vehicle Control Centre. Use 0 if no vehicle information is supplied.

4.3 Sign Clear-down (Message Type 2)

4.3.1 The Clear-down message is used to request that a prediction is removed from an RTPI display.

4.3.2 The message includes a unique identifier for the vehicle and for the stop, allowing signs to identify the relevant departure information that should be cleared.

4.3.3 Vehicles may be able to send a clear-down message when they are arriving at a stop or departing from a stop. Bit 7 of the 5th byte was a reserved value set to zero, but will now (issue 1.5 onwards) be used to indicate an arrival message (0) or a departure message (1).

4.3.4 The table below names the fields, describes their content and details their length in bits.

Field Name	Contents	FieldRef	Length (in bits)
Stop Number	1 to 1048575	SN	20
Vehicle Control Centre	1 to 1023	VCC	10
Vehicle Number	1 to 8191	VN	13
Arrival or departure	0 or 1	AorD	1
Total			**44**

4.3.5 The location of data within the message is defined in the table below.

Byte\bit	D7 msb	D6	D5	D4	D3	D2	D1	D0 lsb
0 (first)	0	0	1	0	SN3	SN2	SN1	SN0
1	SN11	SN10	SN9	SN8	SN7	SN6	SN5	SN4
2	SN19	SN18	SN17	SN16	SN15	SN14	SN13	SN12
3	VCC7	VCC6	VCC5	VCC4	VCC3	VCC2	VCC1	VCC0
4	VN5	VN4	VN3	VN2	VN1	VN0	VCC9	VCC8
5	AorD	VN12	VN11	VN10	VN9	VN8	VN7	VN6

Stop Number [SN0..19]

4.3.6 A numeric identifier for the stop. This nationally unique Clear-down code will be available from the NaPTAN database, published by the Department of Transport.

Vehicle Control Centre [VCC0..9]

4.3.7 A numeric identifier for the vehicle management system that is tracking the vehicles and within which the vehicle numbering system is unique. A unique number will be allocated for particular RTI installations on request. Allocation of the Vehicle Control Centre numbering will initially be coordinated by the RTIG Supplier group.

Vehicle Number [VN0..12]

4.3.8 A numeric identifier for the vehicle, these will be unique within a particular Vehicle Control Centre.

4.4 Enhanced Traffic Light Priority Request (Message Type 3)

4.4.1 This message type was introduced in version 1.6 of the specification to cater for increased numbers of Trigger Points required by some traffic light systems.

4.4.2 A Type 3 message varies from Type 1 only in the TP bit length.

4.4.3 The location of data within the message is defined in the table below

Byte\bit	D7 msb	D6	D5	D4	D3	D2	D1	D0 lsb
0 (first)	0	0	0	1	SD3	SD2	SD1	SD0
1	VNO	MN4	MN3	MN2	MN1	MN0	P1	P0
2	VN8	VN7	VN6	VN5	VN4	VN3	VN2	VN1
3	LVCC3	LVCC2	LVCC1	LVCC0	VN12	VN11	VN10	VN9
4	TSN1	TSN0	TP5	TP4	TP3	TP2	TP1	TP0
5	TSN9	TSN8	TSN7	TSN6	TSN5	TSN4	TSN3	TSN2
6	0	0	0	0	TSN13	TSN12	TSN11	TSN10

Trigger Point [TP0..5]

4.4.4 There are nine user trigger points, normally three triggers are used 0=Registration, 1=Request, 2=Clear. If only one trigger point is being used then 1 (request) should be used.

4.4.5 This message type includes the ability to have more than three trigger points, up to a maximum of nine for use where three is insufficient. A decision on message length should be made during a system design phase as the original type 1 and this type 3 message options are incompatible.

4.4.6 Note that if there is a bus stop close to the junction, the vehicle may wish to send the Request message as it leaves the bus stop.

4.4.7 Trigger point 3 is reserved.