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DISTRIBUTED POWER CONTROL SYSTEM (DPCS) PART-1: RF COMMUNICATION PROTOCOL

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Brief Description

This set of four documents (numbered part 0 to 3) describe the requirements for equipment required for setting up distributed power control for running of trains with diesel electric locomotives. The full set of specifications detail these for requirements of various sub components like, locomotive onboard equipment, radio frequency communications and functional requirements of the equipment with special features for ensuring fail safe operations.

FOREWORD

RDSO had initially issued two separate specifications for Remote Control System of diesel electric locomotives for distributed power applications. After initial field trials need for having interoperability between different makes of remote control systems was realized.

These set of specifications combine and bring together all previous specifications, experience gained through trials and additionally detail features necessarily required for creation of interoperable systems. As of date there are no global standards for interoperability of DPCS. Almost all implementations are of proprietary designs that do not interoperate. The requirements listed here create an initial platform for achieving interoperability. Therefore, interoperability as detailed in these documents is subject to trials. However when the systems described here is paired with identical systems, all features shall be available for distributed power applications.

This set of specifications are also planned to be extended to cover the requirements of Cab Display Unit for setting up End Of Train Telemetry (EOTT) which is under development separately. Sharing of a common radio modem for both DPCS and EOTT applications is the prime consideration. However this feature is planned to be incorporated in a subsequent revision of this specification.

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0 Introduction

This document details the draft communications protocol for Distributed Power Control Systems (DPCS) which shall enable intercommunication between systems supplied by different manufacturers.

This communication protocol is issued as draft for trials and further development. All equipment manufacturers shall implement this draft protocol for inter communication. Each equipment manufacturer shall also implement their proprietary protocol.

The protocol described here shall be used to connect pair and operate equipment sourced from different manufacturers. This shall be done under controlled conditions for trials only.

The regular operations shall be done using the proprietary protocols which shall necessitate use of identical systems for master and remote units.

Note 1: This document is based on the protocol stack requirements for EMD locomotives and needs to be extended to cover requirements for ALCO locomotives**.**

Note 2: In the following description Lead shall be synonymous to Master.

1 Description

1. Every Locomotive is given an unique ID number by the IR. This ID number is used by the DPC system for all transactions. After a formation is made, one of the Locomotive shall be configured as Lead and all other Locomotives shall be configured as Remote Locomotives.

2. Lead Locomotive shall be provided with unique ID's of all Remote Locomotives, which are going to be attached to the Train formation. This shall be done through Display unit keyboard data entry of Lead Loco.

3. The Remote unit shall be provided with its Lead unit ID. This is done through Display unit keyboard data entry in every Remote Locomotive (This is done from safety point of view).

4. The Communication between DPC Lead and DPC Remote/s shall be established with RF baud rate of 9600 bits per second.

5. Each command shall be transmitted in the form of a packet between Lead and Remote units. Before transmitting the packet whether Lead or Remote unit, it shall check the channel (for certain time if it does not received any byte), if it is found free (carrier sense collision avoidance), it shall start transmission.

6. Each packet shall consists of synchronization bits, Lead unit ID(source), Remote unit IDs(destination) along with CRC (BCH) code of the packet. If the packet is corrupted within the air, the CRC calculated for the packet shall not match with the CRC received along with the packet. In such conditions the recipient shall reject the packet.

7. All the data part present in the packet shall be in the encrypted format.

8. After successful reception of each packet, the recipient shall check source unit ID with its ID from which it shall receive the data (Lead ID if the recipient is Remote, Remote ID for which it has sent the request / command if the recipient is Lead) which is stored within its memory and destination unit ID with its own ID, if both are matching then only it shall accept the packet. Otherwise it shall reject it. With this verification; Lead or Remote unit shall accepts the commands from the Locomotives within the same consist (which are configured) and rejects all other packets which are received from the similar units exist in other train consists.

9. When the DPC system is powered ON, it shall read the present configuration and system shall take the confirmation from the driver for continuing with the previous configuration or want to reconfigure the system. From the Configuration; it shall assume the role of Lead or Remote.

9.1. If it is configured as a Lead loco, it shall start to establish communication with the Remote Locomotives whose IDs are given in the configuration. Lead Locomotive shall send the **CFG_COMD** command (which includes the Lead unit ID, Remote unit ID, its position in the train consists) to Remote Locomotives one by one. Remote Locomotive after receiving the **CFG_COMD** command shall verify Remote unit ID with its own ID and verifies the Lead unit ID stored in its memory, if both matched it shall

send **CFG_ACK** to the Lead unit, to indicate that it is ready to accept the commands from Lead unit. In case if Remote unit ID or Lead unit ID not matched with it shall reject the packet.

9.2. If Lead Locomotive does not get **CFG_ACK** from any Remote Locomotive within 60 seconds (by sending the same command in consequent working cycle), it indicates user that particular Remote Locomotive is not able to communicate and reconfigure it, and does not allow the train to move. Once it has get CFG_**ACK** from all Remote units to allow the train to move. This time shall be configurable.

9.3. If it is configured as a Remote Locomotive it shall wait for the communication from the Lead Locomotive.

10. Whenever Lead unit is not able to communicate with any Remote unit in the preset time it shall declare communication failure. This time shall be configurable.

11. Following are the Driver commands that shall be periodically sent from Lead unit to Remote units

S. No.	Parameter	Unit	Range	No of bytes	Bit Resolution
1	CCB_command	Flags	0 – 255	1	NA
2	Discrete Byte1	Flags	0 – 255	1	NA
3	DB_percent	%	0 – 6400	2	1/64
4	TL_Byte1	Flags	0 – 255	1	NA
5	TL_Byte2	Flags	0 – 255	1	NA
6	TL_Byte3	Flags	0 – 255	1	NA
7	spare		0	1	NA
8	ER (Equalizing reservoir pr.)	Kg/cm2	0 – 11000	2	3/5884
9	BP_pressure	Kg/cm2	0 – 11000	2	3/5884
10	BC_pressure	Kg/cm2	0 – 10200	2	3/5884
11	spare	-	0	2	NA
12	spare	-	0	2	NA
13	CREW_Message (Acknowledge)	NUM		2	1

Table 1: Drivers Commands

12. There shall be total of 20 bytes in the drive command packet as described above. The details of individual byte in the command is given below

Parameter	Bit Position	Name	Remarks
CCB_command	0	Emergency Brake	(1 – Apply, 0 – Release)
	1	Penalty Brake	(1 – Apply, 0 – Release)
	2	Bail Off	(1 – Apply, 0 – Release)
	3	Spare	0
	4	brake pipe cut out	(1 – cut out , 0 – cut in)
	5	spare	0
	6	DPC CCB	(1 – disable, 0 – Enable (Brake Isolate))
	7	Direct brake	(1 – disable, 0 – Enable)
Discrete Byte1	0	spare	0
	1	Crew active	(1 – Active, 0 -Not active)
	2	Locked wheel	(1 – Locked, 0 - normal)
	3	Fire alerter	(1 – ON, 0 – OFF)
	4	PCS dropped	(1 – Dropped, 0 - OK)

Parameter	Bit Position	Name	Remarks
	5	spare	0
	6	spare	0
	7	spare	0
TL byte 1	0	Spare	0
	1	Alarm(2T)	(1 – ON, 0 – OFF)
	2	D Valve(3T)	(1 – ON, 0 – OFF)
	3	spare	0
	4	Spare	0
	5	Generator Field(6T)	(1 – ON, 0 – OFF)
	6	C Valve(7T)	(1 – ON, 0 – OFF)
	7	Direction Control = F(8T)	(1 – ON, 0 – OFF)
TL byte 2	0	Direction Control = R (9T)	(1 – ON, 0 – OFF)
	1	Wheel Slip(10T)	(1 – ON, 0 – OFF)
	2	Spare	0
	3	B Valve(12T)	(1 – ON, 0 – OFF)
	4	Spare	0
	5	TE_limiting (14T)	(1 – ON, 0 – OFF)
	6	A Valve(15T)	(1 – ON, 0 – OFF)
	7	Engine Run(16T)	(1 – ON, 0 – OFF)
TL byte 3	0	DB_setup(17T)	(1 – ON, 0 – OFF)
	1	AEBMU (18T)	(1 – ON, 0 – OFF)
	2	Spare	0
	3	Brake_warning(20T)	(1 – ON, 0 – OFF)
	4	DB_excitation (21T)	(1 – ON, 0 – OFF)
	5	Spare	0
	6	Manual sand(23T)	(1 – ON, 0 – OFF)
	7	Air_comp_sync(25T)	(1 – ON, 0 – OFF)

Table 2: Details of drive command packet

13. After receiving above commands from Lead unit, Remote unit shall process through the Locomotive control computer, if the Locomotive control computer is unable to execute the command; it shall indicate it by fault. The Remote DPC unit shall send this status (command execution) along with fault (if any) to the Lead DPC unit.

14. The status parameters that are to be transmitted from Remote Locomotive to Lead Locomotive are as follow.

S. No	Parameters	units	Range	No of bytes	Bit Resolution
1	CCB_status	Flags	0 – 255	1	NA
2	Discrete Byte	Flags	0 – 255	1	NA
3	DB_percent	%	0 – 6400	2	1/64
4	TL_Byte1	Flags	0 – 255	1	NA
5	TL_Byte2	Flags	0 – 255	1	NA
6	TL_Byte3	Flags	0 – 255	1	NA

S. No	Parameters	units	Range	No of bytes	Bit Resolution
7	Spare	-	0	1	NA
8	ER (Equalizing reservoir pr.)	Kg/cm2	0 – 11000	2	3/5884
9	BP_pressure	Kg/cm2	0 – 11000	2	3/5884
10	BC_pressure	Kg/cm2	0 – 10200	2	3/5884
11	spare2		0	2	NA
12	spare3		0	2	NA
13	MRPR	kg/cm2	0 – 2656	2	1/167 ,offset 819
14	Loco_speed	Kmph	0 - 180	2	1/64
15	Notch	NUM	0 – 8	1	1
16	Spare4		0	1	NA
17	Grid_Power_kw	Kwatts	0 - 3000	2	0.25
18	Loco_status1	Bits	0 – 65535	2	1
19	Loco_status2	Bits	0 – 65535	2	1
20	Tractive_Effort	KN	0 - 540	2	10/32 , offset 2048
21	Air flow indicator	lpm	0 - 600	2	1
22	TL_13T	volts	0 – 2880	2	1/40
23	BATI	amps	-200 to +200	2	1/5 offset 2047 range: -400 to 400

Table 3: Status Parameters (38 bytes of Status packet)

Parameter	Bit Position	Name	Remarks
CCB Status	0	Emergency Brake	(1 – Applied , 0 – Released)
	1	Penalty Brake	(1 – Applied , 0 – Released)
	2	Bail Off	(1 – Applied , 0 – Released)
	3	Spare	0
	4	brake pipe cut out	(1 – cut out , 0 – cut in)
	5	Spare	0
	6	Spare	0
	7	Spare	0
Discrete Byte	0	Auto Flasher	(1 – ON, 0 - OFF)
	1	Crew active	(1 – Active, 0 -Not active)
	2	Locked wheel	(1 – Locked, 0 - normal)
	3	Fire alerter	(1 – ON, 0 – OFF)
	4	PCS dropped	(1 – Dropped, 0 - Normal)
	5	Air Flow Sensor	(1 – OK, 0 – Fail)
	6	Eng Shut down	(1 – Engine OFF, 0 – Engine Running)
	7	Sand ON Alarm	(1 – ON, 0 – OFF)
TL byte 1	0	Spare	0
	1	Alarm(2T)	(1 – ON, 0 – OFF)
	2	D Valve(3T)	(1 – ON, 0 – OFF)

Parameter	Bit Position	Name	Remarks
	3	spare	0
	4	Spare	0
	5	Generator Field(6T)	(1 – ON, 0 – OFF)
	6	C Valve(7T)	(1 – ON, 0 – OFF)
	7	Direction Control = F(8T)	(1 – ON, 0 – OFF)
TL byte 2	0	Direction Control = R (9T)	(1 – ON, 0 – OFF)
	1	Wheel Slip(10T)	(1 – ON, 0 – OFF)
	2	Spare	0
	3	B Valve(12T)	(1 – ON, 0 – OFF)
	4	Spare	0
	5	TE_limiting (14T)	(1 – ON, 0 – OFF)
	6	A Valve(15T)	(1 – ON, 0 – OFF)
	7	Engine Run(16T)	(1 – ON, 0 – OFF)
TL byte 3	0	DB_setup(17T)	(1 – ON, 0 – OFF)
	1	AEBMU (18T)	(1 – ON, 0 – OFF)
	2	Spare	0
	3	Brake_warning(20T)	(1 – ON, 0 – OFF)
	4	DB_excitation (21T)	(1 – ON, 0 – OFF)
	5	Spare	0
	6	Manual sand(23T)	(1 – ON, 0 – OFF)
	7	Air_comp_sync(25T)	(1 – ON, 0 – OFF)
Locomotive Status Bits 1	0	engine_off	(1 – Yes, 0 - No)
	1	engine_run	(1 – Yes, 0 - No)
	2	handle_idle	(1 – Yes, 0 - No)
	3	motoring	(1 – Yes, 0 - No)
	4	dynamic_brake	(1 – Yes, 0 - No)
	5	coasting	(1 – Yes, 0 - No)
	6	cranking	(1 – Yes, 0 - No)
	7	air_brake	(1 – Yes, 0 - No)
	8	gen_fed_request	(1 – Yes, 0 - No)
	9	Work on electric brake	(1 – Yes, 0 - No)
	10	Work on power	(1 – Yes, 0 - No)
	11	propulsion	(1 – Yes, 0 - No)
	12	Work on propulsion	(1 – Yes, 0 - No)
	13	prop_request	(1 – Yes, 0 - No)
	14	low_idle	(1 – Yes, 0 - No)
	15	cranking_started	(1 – Yes, 0 - No)
Locomotive Status Bits 2	0	lubrication_start	(1 – Yes, 0 - No)
	1	Turbo pump_ON	(1 – Yes, 0 - No)
	2	Fuel pump_ON	(1 – Yes, 0 - No)

Parameter	Bit Position	Name	Remarks
	3	AGFB_ON	(1 – Yes, 0 - No)
	4	Independent brake Applied	(1 – Yes, 0 - No)
	5	Emergency brake Applied	(1 – Yes, 0 - No)
	6	VCD_MU	(1 – Yes, 0 - No)
	7	VCD_X	(1 – Yes, 0 - No)
	8	memory_freeze	(1 – Yes, 0 - No)
	9	Spare	0
	10	Spare	0
	11	Spare	0
	12	Spare	0
	13	Spare	0
	14	Spare	0
	15	Spare	0

Table 4: Flag definitions in status bytes

Note:- Locomotive status bits indicates the current locomotive operating status. The current operating status shall be defined by setting the corresponding bit in the Locomotive status bytes. At a time one or more bits may be set.

15. Once the CFG_ACK received from all Remote units. The communication shall be considered as established. Communication between Lead and Remote units shall be done as follows.

15.1. Lead unit transmits driver commands to the first Remote unit.

15.2. The Remote unit shall send Status packet along with fault (if any) to the Lead unit in response to the driver command packet. The fault Ack shall be send to the respective Remote unit in the next cycle along with driver command packet.

15.3. Lead unit transmits driver commands to the next Remote unit and the sequence follows till the end Remote loco.

16. If the status packet is not received from any Remote Locomotive the logic for loss of communications as described in Part-0 Annexure 1 shall be followed.

2 Commands

Command Name	Functionality
HOW_DO_U_DO	To find the health of the radio channel at the power ON of the unit
FINE	Response to the health query from the slave unit
CFG_COMD	To get the confirmation from train unit to work as a Remote unit
CFG_ACK	Remote unit send this command to indicate Lead unit that it accepts to work as a Remote unit in the train consists
VER_REQ	Lead requests the version of the Remote unit
VER_NO_ACK	Remote unit responds with the version no
DRV_COMM_XMIT	Transmits the driver commands packet to each Remote unit
FDB_STS	Transmits the status of Remote unit to Lead unit
DPC_DISABLE	Indication of the Linking mode disabled of the unit to the other entities
DPC_DISABLE_ACK	Acknowledge from the other entities indicating the unit to stop communication

Table 5: Valid Commands

S. No	LEAD to Remote loco	Remote to LEAD loco	Remarks
Health Check			
1	HOW_DO_ U_DO		Lead unit check the health of the redundant data radio periodically.
2		FINE	Remote unit responds with the FINE through the redundant data radio.
Get Acceptance from Remote unit to work as Remote unit in Train consists			
3	CFG_COMD		Lead unit transmits the CFG_COMD command to each Remote unit to indicate them it is going to work as Lead with those Remote units.
4		CFG_ACK	After receiving CFG_COMD Remote unit checks the Lead unit ID that is received with packet with the ID stored in its memory and send the CFG_ACK to that Lead unit to indicate that it has accepted to work as a Remote unit in the train consists.
If[3] is No Response, retransmit the CFG_COMD, in the next working cycle If[4] is CFG_ACK received from all Remote units, then go for Transmitting the VER_REQ.			
5	VER_REQ		Lead unit requests for the Software version no of Remote unit.
6		VER_NO_ACK	Remote unit send its version number.
If the Remote unit version matches with the Lead unit version no, it proceeds further to transmit the driver commands to all Remote units. If the Remote unit version mismatches with the Lead unit, it shall log the information in the memory and proceeds further.			
Linking mode disable Indication			
7	DPC_DISABLE		Indication that the Linking mode is disable to the other entities
8		DPC_DISABLE_ACK	Acknowledge from the other entities indicating that the device has recognized that other entity is disabled.
Driver Command Transmission			

S. No	LEAD to Remote loco	Remote to LEAD loco	Remarks
9	DRV_COMM_XMIT		Lead unit transmits the driver commands (Train line and pressure information)to the Remote locos. In the same packet it shall send the Acknowledgment of the previous fault received of the particular Remote unit.
10		FDB_STS_DATA	After execution of driver commands sent by Lead loco, the Remote unit responds the Lead unit with the feedback / status and fault information.
If Status is received with in a timeout it shall send commands to next Remote loco. If Status is not received with in a timeout increment the fail count of communication with that Remote unit and send commands to next Remote loco.			

Table 6: Command Communication Sequence

3 General Format of the Packet

The packet format of the radio protocol is in the following format. It consist of bit sync, Frame sync, message length, message identifier, Lead unit ID, Remote unit ID, Message Data, CRC of the packet data and End of Frame.

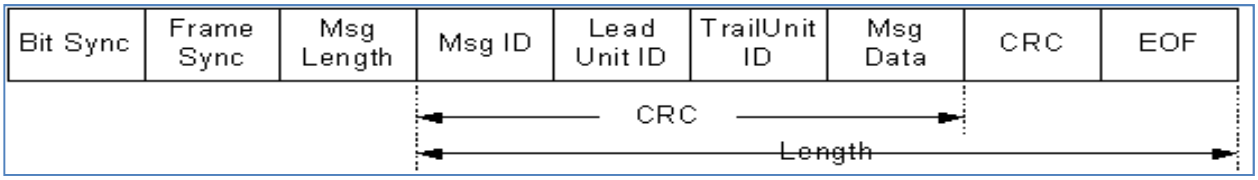

Figure 1: Message Data Block

Command / Status Data	CRC
CRC ← →	

Table 7: CRC

Bit Sync comprises of 0xAA and Frame Sync comprises of 0x47. Message Identifiers and the data transmitted through the identifiers is given below.

3.1 Message ID H (0x0B)

This message Id is used for sending the HOW_DO_ U_DO, FINE, CFG_CMD, CFG_ACK, VER_REQ, VER_NO, DPC_DISABLE, DPC_DISABLE_ACK commands

All two byte commands shall be identified with Message ID H.

HOW_DO_ U_DO (0x33) (L -> R) (Lead to Remote)

FINE (0x34) (R -> L)

CFG_CMD (0x35) (L -> R)

CFG_ACK (0x36) (R -> L)

VER_REQ (0x37) (L -> R)

VER_NO_ACK (0x38) (R -> L)

DPC_DISABLE (0x40) (L -> R)(R -> L)

DPC_DISABLE_ACK (0x41) (R ->L)(L ->R)

72bits	8 Bits	8 bits	6 bits	17 bits	17 bits	8 bits	8 bits	16 bits	8 bits
Bit sync	Frame sync	Messag e length	Msg type identifier H	Lead unit ID 00000-99999 (binary)	Remote unit ID 00000-99999 (binary)	HDU, FINE, CFG_CMD, CFG_ACK, VER_REQ, VER_ACK, DPC_DISAB LE, DPC_DISAB LE_ACK	Remote_p osition, Version no.	CRC Code	End of Frame

DPC_DISABLE command can be initiated by the Remote also if the configuration is disabled in the Remote. i.e., if the DPC system of Remote is disabled then it has to send the DPC_DISABLE command to the Lead with which it has previously communicated. The Lead has to send the acknowledgment for that, so that the Remote shall go into the disable mode.

3.2 Message ID D (L -> R) (0x0C)

All driver commands shall be identified with Message ID D.

72bits	8 Bits	8 bits	6 bits	17 bits	17 bits	15 bytes	16 bits	8 bits
Bit sync	Frame sync	Message length	Msg type identifier D	Lead unit ID 00000-99999	Remote unit ID 00000-99999	Driver commands	BCH Code	End of Frame

3.3 Message ID S (R -> L) (0x0D)

The status of Remote Locomotives is identified with Message ID FS.

72bits	8 Bits	8 bits	6 bits	17 bits	17 bits	35 bytes	16 bits	8 bits
Bit sync	Frame sync	Message length	Msg type identifier S	Lead unit ID 00000-99999	Remote unit ID 00000-99999	Feedback / Status	BCH Code	End of Frame

4 Communication Flow

The following flowchart illustrates the communication flow logic.

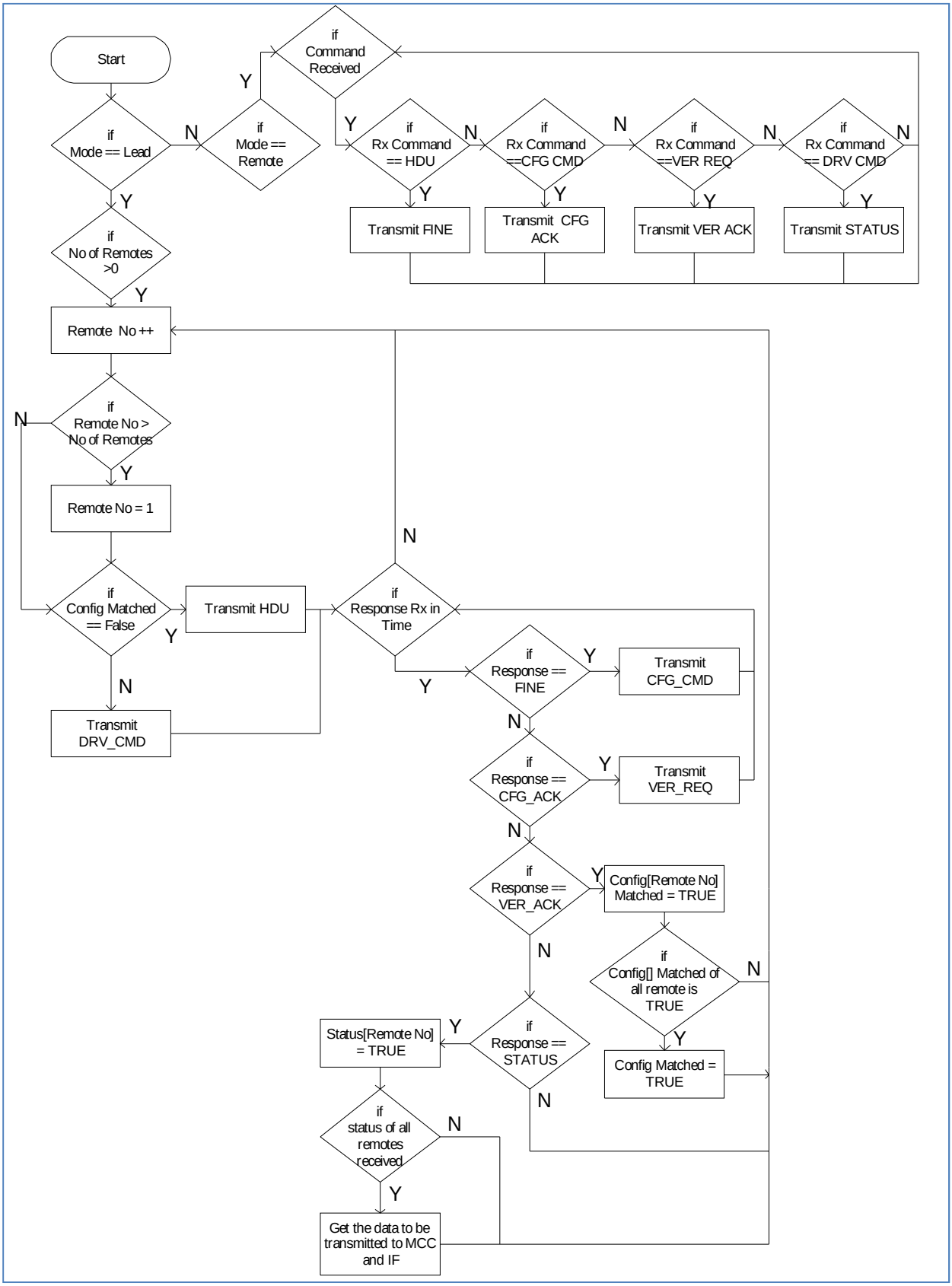

Figure 2: Communication flowchart