CZECH TECHNICAL UNIVERSITY IN PRAGUE

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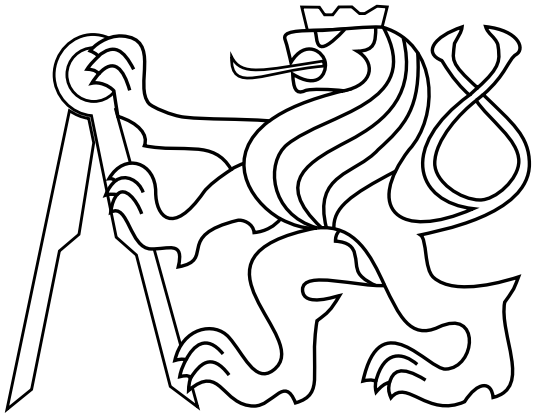

MAV communication protocol

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Contents

1 MAV communication protocol

The protocol is designed for communication between MAVs and between the MAV and the ground station using XBee modules. The ground station operator is able to monitor MAV telemetry. The MAV can be controlled by commands. API frames must be used for communication with XBee. MAV communication protocol (MCP) packets are transferred as a payload of the *ZigBee Transmit Request API frame* and *ZigBee Receive Packet API frame*. The size of the MCP packet is calculated from the head of the XBee API frames.

Several packet types are available. Packet types have tree-like architecture. Packets are divided into packet categories by the value of the first byte (category identifier). Packet categories are shown in table 1.

Packet category	Identifier	Description
Command	0x63 (c)	Packets for MAV control
Telemetry	0x74 (t)	Periodically send telemetry
Report	0x72 (r)	Packets with MAV states
Message	0x6D (m)	Text messages

Table 1: Packet categories

1.1 Command Packets

Command packets are designed for MAV control. *Command packets* start with the command category identifier (0x63 - c). Command type identifier is the second byte of the packet. Command types are shown in table 2. *Report packets* can be obtained by *status request commands*. Each command type have its own *status request command*. Each *status request command* has Get Status identifier (0xFF) on the third byte of the packet.

Command type	Identifier	Description
Telemetry to coordinator	0x01	Choose telemetry, which should be monitored
Landing	0x02	Enable and disable landing
Controllers	0x03	Turn on and off controllers
Trajectory set	0x04	Set trajectory way-points
Position slave set	0x05	Set the slave MAV for coordinate system distribution
Time	0x06	Set time
Position set	0x07	Set new position of the MAV

Table 2: Command types

1.1.1 Telemetry to Coordinator

Telemetry to coordinator command is used to set which telemetry types are send to the ground station for online monitoring. Each telemetry type has specific identifier. MCP supports up to 256 different telemetry types. Identifiers are shown in table 29. *Telemetry to coordinator command packet* consists of four bytes. The structure of the *telemetry to coordinator command packet* is shown in table 3.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x01	Telemetry to coordinator type
On/Off	3	0x01/0x00	Turn sending on or off
Telemetry identifier	4	0x00-0xFF	Identifier of telemetry data

Table 3: Telemetry to coordinator command packet

Telemetry to coordinator status request command is used to obtain *telemetry to coordinator report packet* (section 1.3.1). The *Telemetry to coordinator status request command packet* consists of four bytes. The structure of the *telemetry to coordinator status request command packet* is shown in table 4.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x01	Telemetry to coordinator type
Get Status identifier	3	0xFF	
Telemetry identifier	4	0x00-0xFF	Identifier of telemetry data

Table 4: Telemetry to coordinator status request command packet

1.1.2 Landing

Landing request command is used to turn on and off autonomous landing. *Landing request command packet* consists of three bytes. The structure of the *landing request command packet* is shown in table 5.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x02	Landing type
On/Off	3	0x01/0x00	Turn landing on or off

Table 5: Landing request command packet

Landing status request command is used to obtain *landing report packet* (section 1.3.2). *Landing status request command packet* consists of three bytes. The structure of the *landing status request command packet* is shown in table 6.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x02	Landing type
Get Status identifier	3	0xFF	

Table 6: Landing status request command packet

1.1.3 Controllers

Controllers request command is used to switch between active controller. Each of controller has its own identifier. Controller identifiers are shown in table 28. MCP supports up to 255 controllers. *Controllers request command packet* consists of three bytes. The structure of the *controllers request command packet* is shown in table 7.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x03	Controllers type
Controller identifier	3	0x00-0xFE	Identifier of desired controller

Table 7: Controllers request command packet

Controllers status request command is used to obtain *controllers report packet* (section 1.3.3). *Controllers status request command packet* consists of three bytes. The structure of the *controllers status request command packet* is shown in table 8.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x03	Controllers type
Get Status identifier	3	0xFF	

Table 8: Controllers status request command packet

1.1.4 Trajectory set

Trajectory set request command is used to set trajectory waypoints. To set more than one waypoint, repeat time, elevator position, aileron position and altitude in packet multiple times. *Trajectory set request command packet* consists of $3 + 16k$ bytes, where k is number of trajectory waypoints. The structure of the *trajectory set request command packet* is shown in table 9.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x04	Telemetry set type
Size	3	0x00-0xFE	Number of trajectory waypoints in packet
Time	4-7	uint32	Unsigned 4-byte integer in binary form
Elevator position	8-11	float	4-byte float in binary form
Aileron positon	12-15	float	4-byte float in binary form
Altitude	16-19	float	4-byte float in binary form
Time	20-23	uint32	Unsigned 4-byte integer in binary form
Elevator position	24-27	float	4-byte float in binary form
Aileron positon	28-31	float	4-byte float in binary form
Altitude	32-35	float	4-byte float in binary form
...	...	...	...

Table 9: Trajectory set request command packet

Trajectory set status request command is used to obtain *trajectory set report packet* (section 1.3.4). *Trajectory set status request command packet* consists of three bytes. The structure of the *trajectory set status request command packet* is shown in table 10.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x04	Telemetry set type
Get Status identifier	3	0xFF	

Table 10: Trajectory set status request command packet

1.1.5 Position slave set

Position slave set request command is used to set the slave MAV address for coordinate system distribution. *Position slave set request command packet* consists of ten bytes. The structure of the *position slave set request command packet* is shown in table 11.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x05	Position slave set type
Slave address	3-10	0xXXXXXXXXXXXXXXXX	8-byte slave MAV address

Table 11: Position slave set request command packet

Position slave set status request command is used to obtain *position slave set report packet* (section 1.3.5). *Position slave set status request command packet* consists of three bytes. The structure of the *position slave set status request command* is shown in table 12.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x05	Position slave set type
Get Status identifier	3	0xFF	

Table 12: Position slave set status request command packet

1.1.6 Time

Time request command is used to set time on the MAV. Time is set in seconds in POSIX format (Unix time). *Time request command packet* consists of six bytes. The structure of the *time request command packet* is shown in table 13.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x06	Time type
Current time	3-6	uint32	Unsigned 4-byte integer in binary form

Table 13: Time request command packet

Time status request command is used to obtain *time report packet* (section 1.3.6). *Time*

status request command packet consists of three bytes. The structure of the *time status request command packet* is described in table 14.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x06	Time type
Get Status identifier	3	0xFF	

Table 14: Time status request command packet

1.1.7 Position set

Position set request command is used to set position of the MAV in the new coordinate system. *Position set request command packet* consists of ten bytes. The structure of the *position set request command packet* is shown in table 15.

Packet Fields	Byte	Value	Description
Packet category	1	0x63	Command category
Command type	2	0x07	Position set type
New elevator position	3-6	float	4-byte float in binary form
New aileron positon	7-10	float	4-byte float in binary form

Table 15: Position set request command packet

Position set type does not have status request command, because position of the MAV is one of the telemetry data.

1.2 Telemetry packets

Telemetry packets are used to transfer telemetry from MAV to the ground station. These packets are sent by MAV periodically and consume most of the XBee transfer capacity. *Telemetry packets* start with telemetry category identifier (0x74 - t). *Telemetry packet* consists of $1 + 5k$ bytes, where k is number of transferred telemetry data. The structure

of the *telemetry packet* is shown in table 16. Telemetry identifier and telemetry data are repeated in packet. Telemetry identifiers are shown in table 29.

Packet Fields	Byte	Value	Description
Packet category	1	0x74	Telemetry category
Telemetry identifier	2	0x00-0xFF	Identifier of telemetry data
Telemetry data	3-6	float	4-byte float in binary form
Telemetry identifier	7	0x00-0xFF	Identifier of telemetry data
Telemetry data	8-11	float	4-byte float in binary form
...	...	...	...

Table 16: Telemetry packet

1.3 Report packets

Report packets are used to transfer MAV states. *Report packets* start with report category identifier (0x72 - r). Report type identifier is the second byte of the packet. The report type identifiers correspond with command type identifiers shown in table 2. The report types are shown in table 17.

Report type	Identifier	Description
Telemetry to Coordinator	0x01	Monitored telemetry types
Landing	0x02	Current landing state
Controllers	0x03	Currently active controller
Trajectory set	0x04	Trajectory way-points
Position slave set	0x05	Current slave address
Time	0x06	Current MAV time

Table 17: Report types

1.3.1 Telemetry to Coordinator

Telemetry to coordinator report is used to check whether chosen telemetry type is send to the ground station. *Telemetry to coordinator report packet* consists of four bytes. The structure of the *telemetry to coordinator report packet* is shown in table 18. Each telemetry type has specific identifier. Identifiers are shown in table 29.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Report type	2	0x01	Telemetry to coordinator type
On/Off	3	0x00/0x01	If telemetry data are send
Telemetry type	4	0x00-0xFF	Identifier of telemetry data

Table 18: Telemetry to coordinator report packet

1.3.2 Landing

Landing report is used to monitor current landing state. Each landing state has specific identifier. Landing state identifiers are shown in table 27. *Landing report packet* consists of three bytes. The structure of the *landing report packet* is shown in table 19.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Report type	2	0x02	Landing type
Landing state identifier	3	0x00-0x04	Current landing state

Table 19: Landing report packet

1.3.3 Controllers

Controllers report is used to check which controller is currently active. *Controllers report packet* consists of three bytes. The structure of the *controllers report packet* is shown in table 20. Each controller has specific identifier. Controller identifiers are shown in table 28.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Report type	2	0x03	Controllers type
Controller identifier	3	0x00-0xFE	Currently active controller

Table 20: Controllers report packet

1.3.4 Trajectory set

Trajectory set report is used to monitor current trajectory waypoints. *Trajectory set report packet* consists of $3 + 16k$ bytes, where k is number of trajectory waypoints. The structure of the *trajectory set report packet* is shown in table 21.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Command type	2	0x04	Telemetry set type
Size	3	0x00-0xFE	Number of trajectory waypoints in packet
Time	4-7	uint32	Unsigned 4-byte integer in binary form
Elevator position	8-11	float	4-byte float in binary form
Aileron positon	12-15	float	4-byte float in binary form
Altitude	16-19	float	4-byte float in binary form
Time	20-23	uint32	Unsigned 4-byte integer in binary form
Elevator position	24-27	float	4-byte float in binary form
Aileron positon	28-31	float	4-byte float in binary form
Altitude	32-35	float	4-byte float in binary form
...	...	...	...

Table 21: Trajectory set report packet

1.3.5 Position slave set

Position slave set report is used to monitor current address of the slave MAV. *Position slave set report packet* consists of ten bytes. The structure of the *position slave set report*

packet is shown in table 22.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Command type	2	0x05	Position slave set type
Current slave address	3-10	0xXXXXXXXXXXXXXXXX	8-byte slave MAV address

Table 22: Position slave set report packet

1.3.6 Time

Time report is used to monitor time on the MAV. *Time report packet* consists of six bytes. The structure of the *time report packet* is shown in table 23.

Packet Fields	Byte	Value	Description
Packet category	1	0x72	Report category
Command type	2	0x06	Time type
MAV time	3-6	uint32	Unsigned 4-byte integer in binary form

Table 23: Time report packet

1.4 Message Packets

Message packets are used to send string messages. *Message packets* start message with the message category identifier (0x6D - m). Size of the message packet is $1 + k$, where k is length of the message. Chars in message are coded in 8-bit ascii. Example of a *message packet* is shown in table 24.

Packet Fields	Byte	Value	Description
Packet category	1	0x6D	Message category
Char 1	2	0x48	H
Char 2	3	0x65	e
Char 3	4	0x6C	l
Char 4	5	0x6C	l
Char 5	6	0x6F	o
Char 6	7	0x20	space
Char 7	8	0x77	w
Char 8	9	0x6F	o
Char 9	2	0x72	r
Char 10	3	0x6C	l
Char 11	2	0x64	d

Table 24: Example of a message packet

2 Protocol Identifiers

Packet category	Identifier
Command	0x63 (c)
Telemetry	0x74 (t)
Report	0x72 (r)
Message	0x6D (m)
Warning	0x77 (w)

Table 25: Packet category identifiers

Command type	Identifier
Telemetry to coordinator	0x01
Landing	0x02
Controllers	0x03
Trajectory set	0x04
Position slave set	0x05
Time	0x06
Position set	0x07

Table 26: Command type identifiers

Landing state	Identifier
On ground	0x00
Landing	0x01
Stabilization	0x02
Take off	0x03
Flight	0x04

Table 27: Landing state indetifiers

Controller	Identifier
Manual control	0x01
Altitude controller	0x02
MPC controller	0x03

Table 28: Controllers identifiers

Telemetry	Identifier
Estimated altitude	0x00
Altitude	0x01
Elevator speed	0x02
Aileron speed	0x03
Estimated elevator speed	0x04
Estimated aileron speed	0x05
Elevator position	0x06
Aileron position	0x07
Altitude controller output	0x08
Altitude speed	0x09
Aileron controller output	0x0A
Elevator controller output	0x0B
Altitude setpoint	0x0C
Elevator position setpoint	0x0D
Aileron position setpoint	0x0E
Elevator acceleration	0x0F
Aileron acceleration	0x10
Valid Blob	0x11
Output throttle	0x12
Output elevator	0x13
Output aileron	0x14
Output rudder	0x15
Blob elevator	0x16
Blob aileron	0x17
Blob altitude	0x18
Pitch angle	0x19
Roll angle	0x1A
Elevator shift	0x1B
Aileron shift	0x1C
Elevator acceleration input	0x1D
Elevator acceleration error	0x1E
Aileron acceleration input	0x1F
Aileron acceleration error	0x20

Table 29: Telemetry identifiers