Evaluation of 6LoWPAN Implementations

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It works, but ...

Outline

Motivation

- Goal: Qualitative comparison of 6LoWPAN Implementations
- Some demonstrations for interoperability testing have been shown at Arch Rocks San Francisco headquarters and at the 70th IETF meeting
- This work is the 1st published results considering full interoperability testing

Outline

IEEE 802.15.4

- Low power, low cost radio interface
- Ranges of about 25-50 meters
- Requires mesh routing from the upper layer protocol
- Frame size 127 octets (excluding the frame headers)

octets: 2	1	0/2	0/2/8	0/2	0/2/8	variable	2
Frame control	Sequence number	Destination PAN identifier	Destination address	Source PAN identifier	Source address	Frame payload	Frame sequence check

Figure: IEEE 802.15.4 Header

General

- IPv6 over Low Power Wireless Personal Area Networks
- Adapts IPv6 to IEEE 802.15.4 devices
- IPv6 compatible
- Without using too much resources

Dispatch Header and Type

- The dispatch selector is always the first header in a sequence of headers
- The dispatch header defines which header is the next in the sequence of headers

octets: 1	40	variable
Header type (IPv6 Dispatch)	IPv6 header	Payload

octets: 1	1	variable	variable
Header type (HC1 Dispatch)	HC1 encoding	IPv6 header fields	Payload

Compression

- HC1 compression for the IPv6 header
- Reduces the size in the best case by 39 octets
- Only compresses link-local addresses
- HC2 compression for the UDP header

Compression

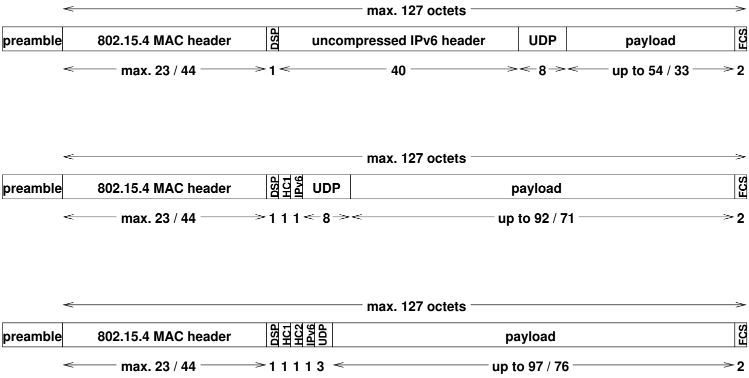

Figure: Uncompressed and compressed 6LoWPAN header

Fragmentation

- IPv6 minimum MTU 1280 octets
- IEEE 802.15.4 frame size 127 octets
- 6LoWPAN defines fragmentation and reassembly process
- 1 minute timeout for reassembly
- Often only 1 buffer available

Mesh Routing

- Maximum radio range 25m indoors / 50m outdoors
- Widespread networks impossible without mesh routing
- Intermediate motes act as routers

Multicasting

- Used for discovering the IP to MAC mapping
- 802.15.4 does not support multicasting, only broadcasting is available
- All the tested 6LoWPAN implementations relied on 802.15.4 broadcasting
- There is a discussion in the IETF to replace broadcasting by a state full system

Outline

Implementations

Table: List of 6LoWPAN Implementations

Name	OS / License	Hardware	Maintained
Jacobs	TinyOS / 3BSD	Telos B, . . .	no
Berkeley IP	TinyOS / 3BSD	Telos B, . . .	active
Arch Rock	TinyOS / EULA	Raven, . . .	active
SICSlowpan	Contiki / 3BSD	Raven, . . .	active
Sensinode	Own / EULA	Sensinode	active
Hitachi	Own / EULA	Renesas	unknown

TelosB

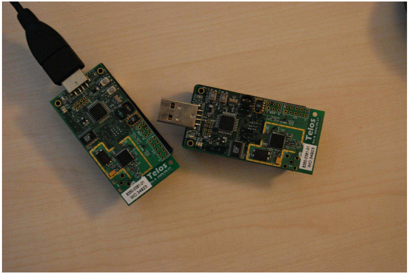

Figure: TelosB motes

- Texas Instruments MSP430
- 10k Ram
- 48k Flash Memory
- USB to Serial Port

Amtel Raven

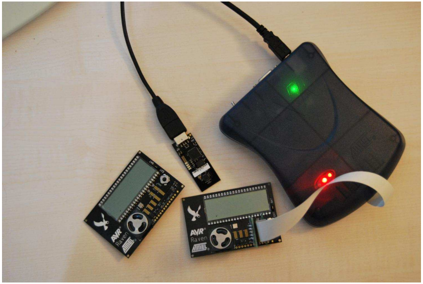

Figure: Raven Motes, USB stick and Programming kit

- ATmega3290P for User IO operations
- ATmega1284P for the RF Stacks
- Serial LCD Display

Mote Setup

- Motes are placed next to each other
- Minimizes interference
- Maximum signal strength

Figure: Mote positions for mesh routing and interoperability

Outline

Framing

- All the 6LoWPAN implementations utilize IEEE 802.15.4 frame format
- The Jacobs implementation uses the TinyOS Active Message format
  - First 6LoWPAN implementation for TinyOS
  - Active Message was the only available option for communication at that time
  - Active Message inserts an additional field between the IEEE802.15.4 header and the 6LoWPAN header

Dispatch Header

- Well supported by all 6LoWPAN implementations
- All Dispatch codes are supported

Compression Header

- HC1 is supported by all 6LoWPAN implementations
- HC2 for UDP is supported by Arch Rock only at the interoperability evaluation time
- Contiki and Arch Rock support not only the local link compression but also a global and state full compression

Fragmentation Header

- Tested by sending ICMP echo requests of different sizes
- Fragmentation is supported by all the 6LoWPAN implementations
- Drop rate of a big IPv6 packet is higher than the drop rate of the smaller packet with the same accumulative size

Mesh Routing

- Tested by moving two motes out of the radio range and placing a third in between
- Supported by Berkeley IP, Contiki, and Arch Rock
- Drop rate higher than the accumulated drop rate of the two hops

Multicasting

- All the tested 6LoWPAN implementations relied on broadcasting for neighborhood discovery
- Broadcasting is also used for mesh neighborhood discovery
- Works reliable in the mote local range

Summary

Table: Implemented features: + means supported and tested, o means supported but not tested, - means not supported

Feature	Jacobs	Berkeley	Contiki	Arch Rock
Dispatch Header	+	+	+	+
Dispatch Type	+	+	+	+
Mesh Routing & Header	-	+	+	+
Multicasting Header	-	+	+	+
Multicasting	+	+	+	+

Summary

Table: Implemented features: + means supported and tested, o means supported but not tested, - means not supported

Feature	Jacobs	Berkeley	Contiki	Arch Rock
Fragmentation	+	+	+	+
HC1	+	+	+	+
HC2 for UDP	-	-	-	+
HC1g	-	-	o	o
ICMPv6 Echo	+	+	+	+

Outline

Conclusions

- It works!
- For ArchRock, SICSlowpan, and Berkeley IP
- Not for all channels
- Arch Rock seems to dislike Berkeley IP motes with smaller mote numbers

Conclusions

- The 6LoWPAN implementations are following the 6LoWPAN standard pretty well
- The documentation provided for the 6LoWPAN implementations is inadequate
- Further investigation needed for fragmentation, mesh routing, mote and channel number selection
- Quantitative performance analysis is a potential future work

THANK YOU

Questions?