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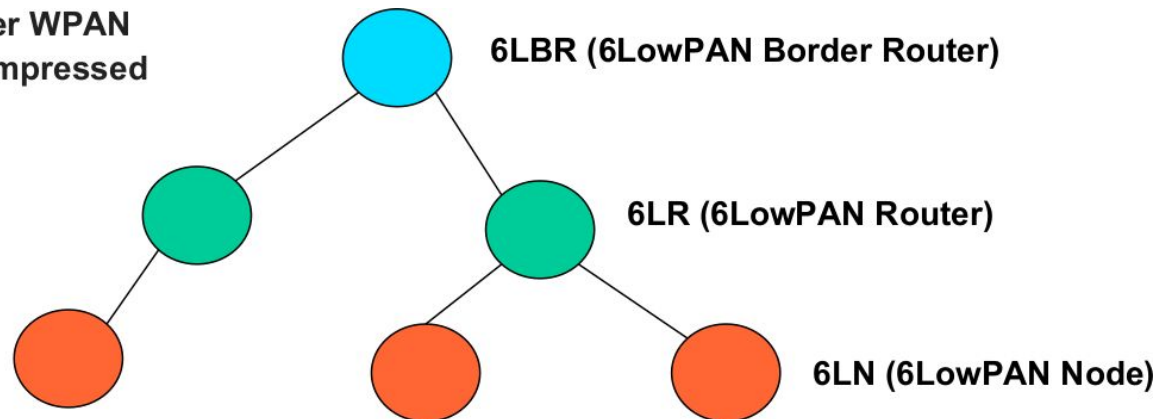
RPL

Networks and Protocols 1

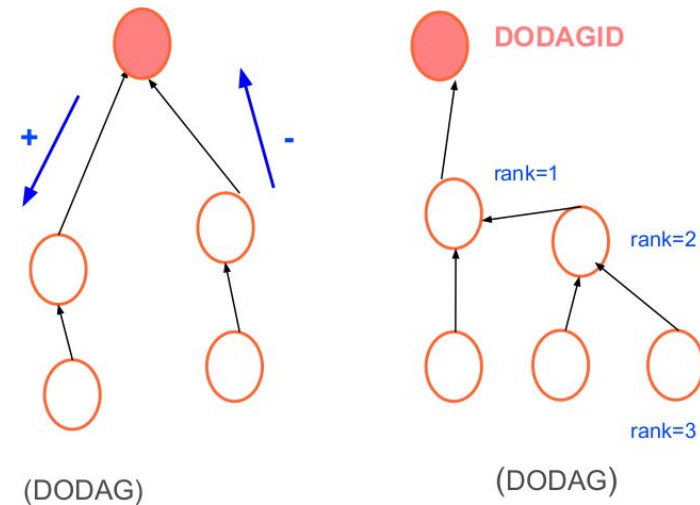
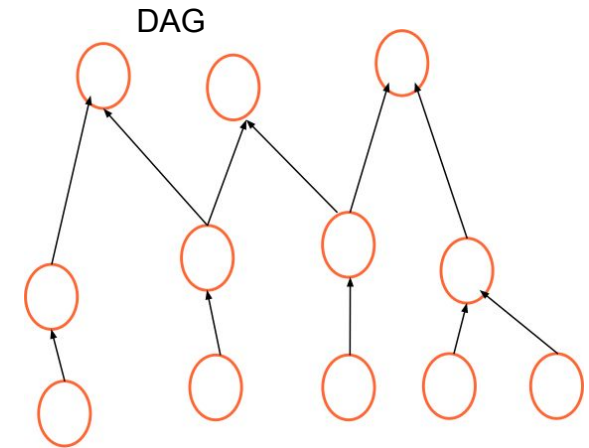
Facultad de Informática

- IPv6 Routing Protocol for Low Power Lossy Networks
 - Specified by the IETF, [RFC6550](#)
- Distance Vector Routing Protocol
 - Each node maintains a table of distances to all the other nodes of the network
 - address of next hop
 - distance/cost
 - Simpler and less overhead than link state algorithms
- Intra domain routing
- Topological changes are notified to neighbors

IPv6 over Low power WPAN
(6lowpan) - IPv6 compressed

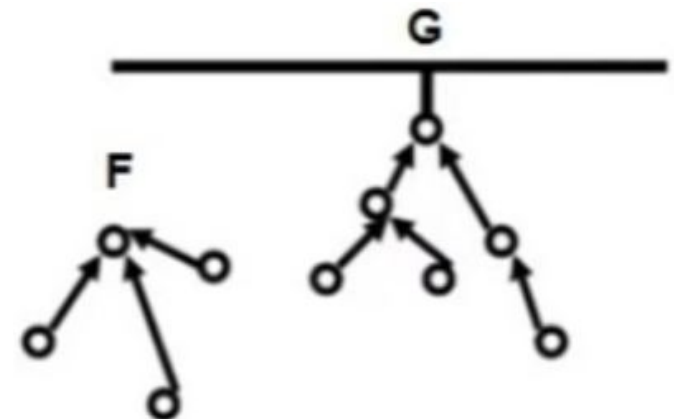
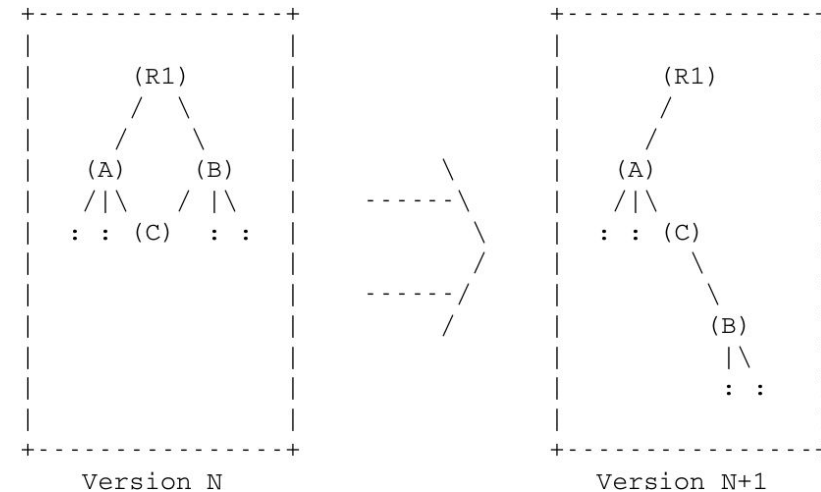


- **DAG: Acyclic Directed Graph**
 - Oriented edges
 - No cycles
 - A node can have more than one edge
- **DAG Root:**
 - A node with no output edges
- **DODAG: Destination Oriented DAG**
 - A DAG with only one root
- **DODAG Root:**
 - The root of the DODAG
 - Act as a border/edge router
 - Has a DODAGID
- **Up: upstream flow**
- **Down: downstream flow**
- **Rank: distance to the root**

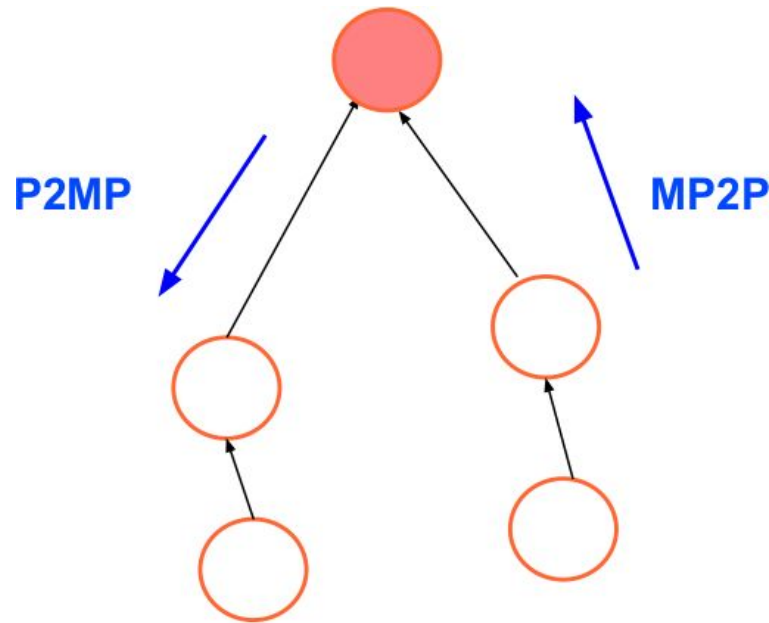


- Objective function:
 - How to compute the rank
- RPLInstanceID: unique id for the RPL network
- RPL Instance:
 - A set of one or more DODAGs with the same RPLInstanceID and objective function
 - A node may belong to more than one DODAGs
- Storing Nodes:
 - store the complete routing table
- Non Storing Nodes:
 - Only store the parents

- **DODAG Version:**
 - specific iteration (“version”) of the DODAG
- **DODAGVersionNumber:**
 - version number
- **GOAL:** external machine that the DODAGS wants access to
- **Grounded DODAG:**
 - Can reach the GOAL
- **Floating DODAG:**
 - Cannot reach the GOAL



- Three flows
 - Multi Point to Point (MP2P)
 - Point to Multi Point (P2MP)
 - Point to Point (P2P)
- RPL is optimised for MP2P

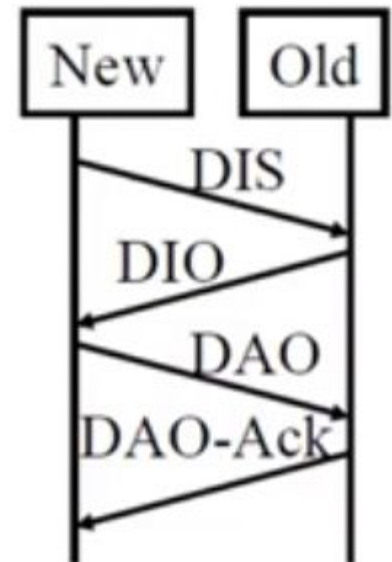


(DODAG)

- New ICMPv6 control packets

Type=155	Code	Checksum
Base		
Option(s)		

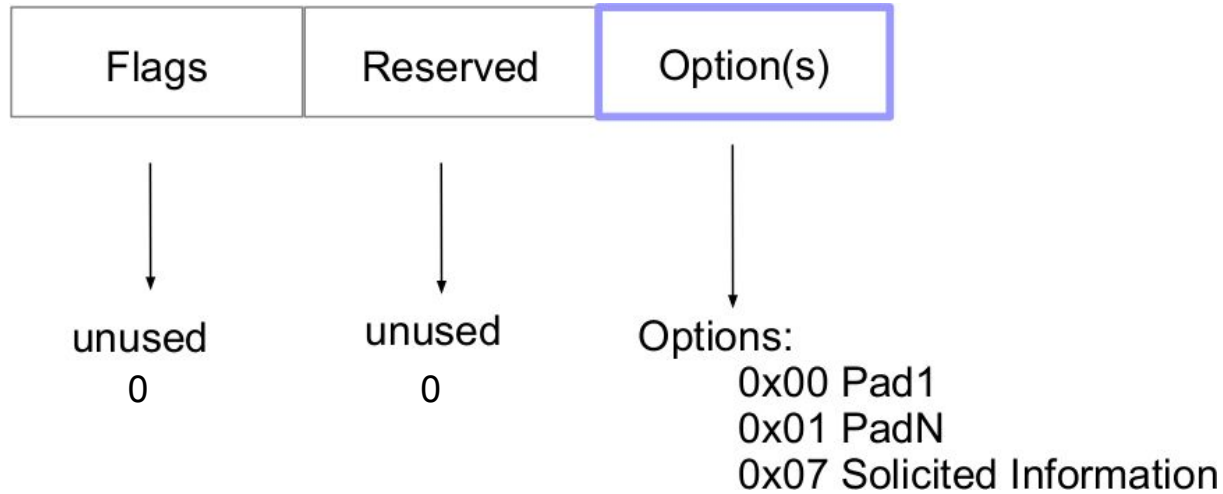
- Code identifies the type of message
 - 0x00: DODAG Information Solicitation (DIS)
 - 0x01: DODAG Information Object (DIO)
 - 0x02: Destination Advertisement Object (DAO)
 - 0x03: DAO-ACK



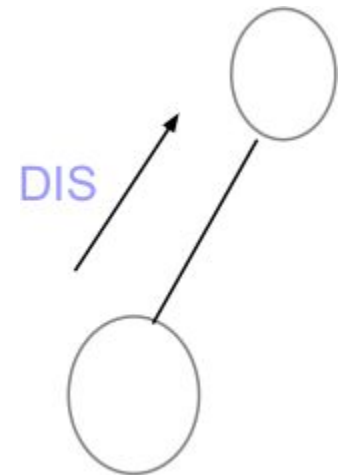
- New ICMPv6 packets

Type=155	Code	Checksum
Security		
Base		
Option(s)		

- Code identifies the type of message:
 - 0x80: **Secure** DIS (**S**DIS)
 - 0x81: **Secure** DIO (**S**DIO)
 - 0x82: **Secure** DAO (**S**DAO)
 - 0x83: **Secure** DAO-ACK (**S**DAO-ACK)
 - 0x8A: Consistency Check



- Equivalent to the RS in IPv6 NDP
- Sent upstream to request a DODAG Information Object (DIO)



DODAG Information Object (DIO)

RPLInstanceID				Version Number	Rank	
G	0	MOP	Prf	DTSN	Flags	Reserved
<p>DODAGID</p> <p>IPv6 address of the DODAG root</p>						
Option(s)						

Field	Interpretation
G	1 - Grounded, 0 - Floating
Prf	DAGPreference 0-7, 0 lower preference
DTSN	Destination Advertisement Trigger Sequence Number, to maintain downward routes
Flags	no usado, deben ser 0
Reserved	no usado, deben ser 0

MOP	Operation Mode
0	Not maintain downward routes
1	Non Storing Mode
2	Storing Mode without multicast
3	Storing Mode with multicast
4-7	reservado

Type	Options
0x00	PAD1
0x01	PADN
0x02	DAG Metric Container
0x03	Routing Information
0x04	DODAG Configurariion
0x08	Prefix Information

Sent periodically by routers or as a response to a DIS

Sends downstream the DODAG Information

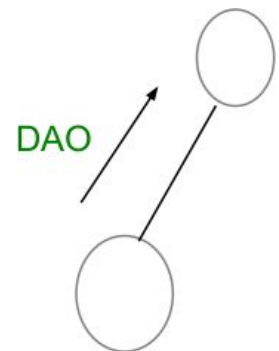
DODAG Advertisement Object (DAO)

RPLInstanceID	K	D	Flags	Reserved	DAOSequence
<p style="text-align: center;">DODAGID</p> <p style="text-align: center; color: red;">IPv6 address of the DODAG root</p>					
Option(s)					

Field	Interpretation
K	Requiere DAO-ACK
D	DODAGID present
Flags	not used, 0
Reserved	not used, 0
DAOSequence	Sequence number copied on the DAO-ACK

Type	Options
0x00	PAD1
0x01	PADN
0x05	RPL Target
0x06	Transit Information
0x09	RPL Target Descriptor

- Used to send information upwards



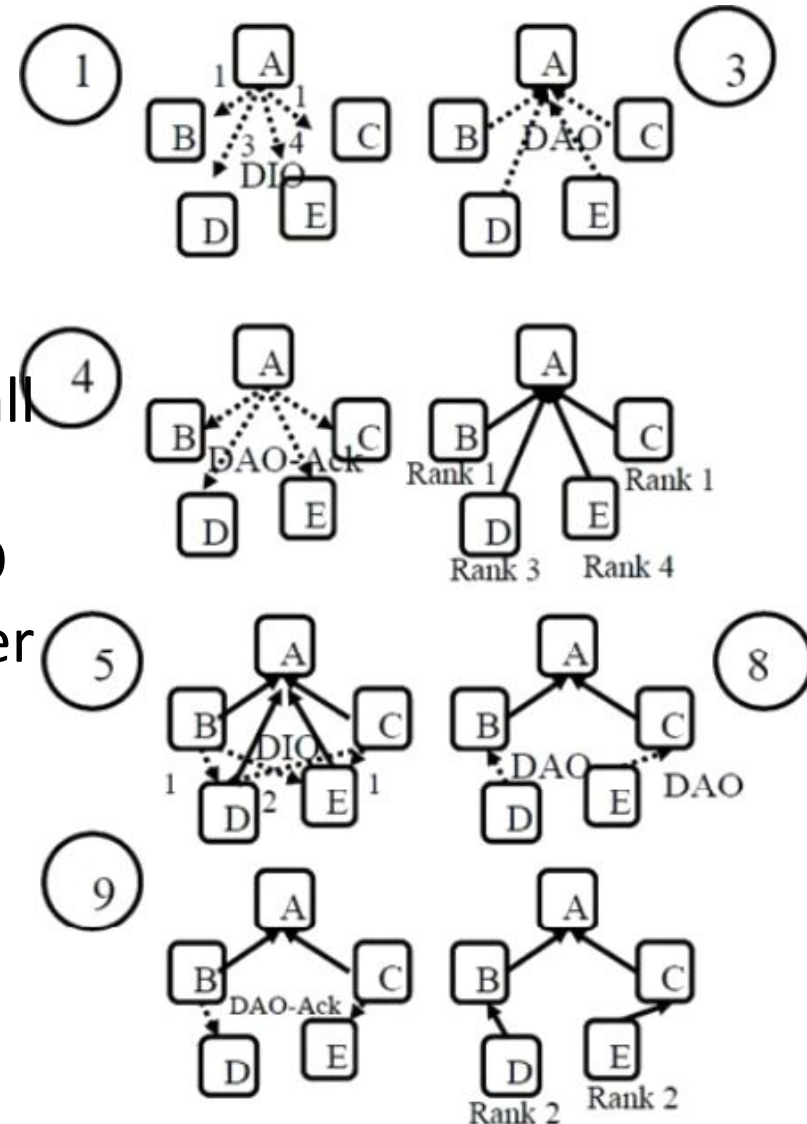
RPLInstanceID	D	Reserved	DAOSequence	Status
<p>DODAGID</p> <p>IPv6 address of the DODAG root</p>				
Option(s)				

Status	Interpretation
0	Aceptado sin condiciones
1-127	Aceptado, pero se sugiere buscar un padre distinto
128-255	Rechazado, el nodo que envía el DAO-ACK rechaza actuar como padre

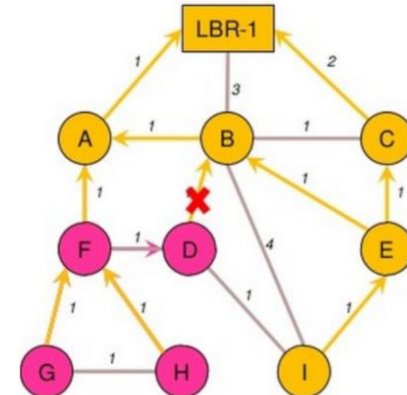
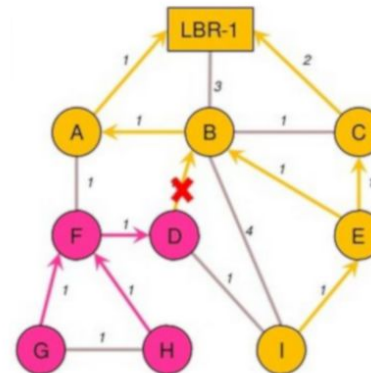
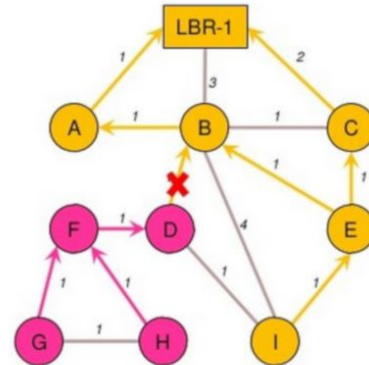
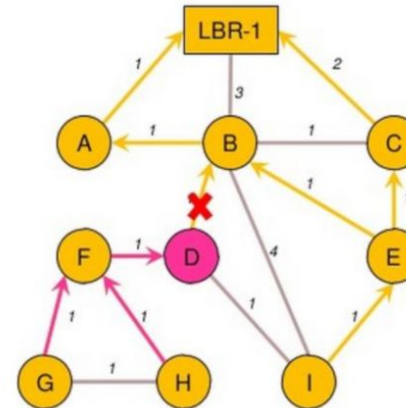
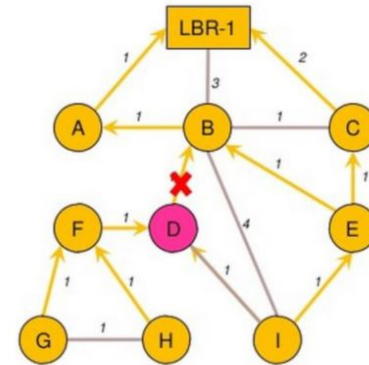
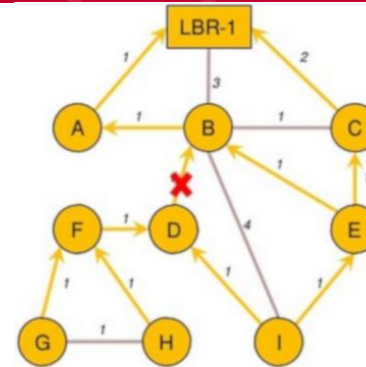
Sent as response to a DAO message

DODAG formation

1. The DODAG Root (A) sends DIO
2. On reception the nodes compute the rank to A
3. The nodes send a DAO
4. El DODAG Root accepts confirms all with DAO-ACK (accepts)
5. Nodes start sending their own DIO
6. D observes that it will have a better rank through B
7. E observes the same with C
8. D and E send DAO messages to B and C
9. B and C confirm with a DAO-ACK (accept)



1. Link between D and B breaks
2. D sends a DIO to notify the changes in its sub-DAG
 - I remains in the DODAG through E
 - I removes D from the list of parents
3. F sends DIO to G and H
4. G and H join the floating DODAG
5. F receives a DIO from A
6. F sends DAO to A and joins again the DODAG LBR-1
 - Removes D from the list of parents



- You will use Cooja to simulate a 6LoWPAN network that uses RPL
 - <https://sourceforge.net/projects/contiki/files/Instant%20Contiki/>
 - `# cd ~/contiki/tools/cooja/`
 - `# ant run`
- You can analyze the network traffic with Wireshark by exporting PCAP files of the simulated traffic
 - You can eliminate duplicate packets with the edicap tool:
`# editcap -d original_file.cap filtered-output.cap`
- To infer the DODAG topology you can
 - Filter the DIO and DAO messages
 - Activate the debug information in `~/contiki/core/net/rpl/rpl-dag.c` and call `rpl_print_neighbor_list()` from the `rpl_process_dio()` function
 - Filter UDP messages and analyse the 802.15.4 addresses to see the preferred routes for the UDP packets
 - Move/eliminate/add nodes and see how the RPL network converges

Applications Places

My simulation - Cooja: The Contiki Network Simulator

File Simulation Notes Tools Settings Help

View Zoom

Network...
Mote output...
Timeline...
Breakpoints...
Radio messages...
Simulation script editor...
Notes...
Buffer view...
Base RSSI...
Mote radio duty cycle...
Mote Information
Mote Interface Viewer
Variable Watcher
Msp CLI
Msp Code Watcher
Msp Stack Watcher
Msp Cycle Watcher
Serial Socket (CLIENT)
Serial Socket (SERVER)
Collect View

Simulation control

Run Speed limit

Start Pause Step Reload

Time: 00:00.000
Speed: ---

Notes

Enter notes here

Mote output

File Edit View

Time	Mote	Message

Filter:

Timeline showing 11 motes

File Edit View Zoom Events Notes

```
1
2
3
4
5
/* Send no-path DAO only to preferred parent, if any */
```

netstat -nr | awk '{ if (\$2 == "tun0" { print \$1, \$3, \$4, \$5, \$6, \$7, \$8, \$9, \$10, \$11, \$12, \$13, \$14, \$15, \$16, \$17, \$18, \$19, \$20, \$21, \$22, \$23, \$24, \$25, \$26, \$27, \$28, \$29, \$30, \$31, \$32, \$33, \$34, \$35, \$36, \$37, \$38, \$39, \$40, \$41, \$42, \$43, \$44, \$45, \$46, \$47, \$48, \$49, \$50, \$51, \$52, \$53, \$54, \$55, \$56, \$57, \$58, \$59, \$60, \$61, \$62, \$63, \$64, \$65, \$66, \$67, \$68, \$69, \$70, \$71, \$72, \$73, \$74, \$75, \$76, \$77, \$78, \$79, \$80, \$81, \$82, \$83, \$84, \$85, \$86, \$87, \$88, \$89, \$90, \$91, \$92, \$93, \$94, \$95, \$96, \$97, \$98, \$99, \$100, \$101, \$102, \$103, \$104, \$105, \$106, \$107, \$108, \$109, \$110, \$111, \$112, \$113, \$114, \$115, \$116, \$117, \$118, \$119, \$120, \$121, \$122, \$123, \$124, \$125, \$126, \$127, \$128, \$129, \$130, \$131, \$132, \$133, \$134, \$135, \$136, \$137, \$138, \$139, \$140, \$141, \$142, \$143, \$144, \$145, \$146, \$147, \$148, \$149, \$150, \$151, \$152, 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Applications Places

radiolog-1539180843814.pcap [Wireshark 1.7.2 (SVN Rev 42506 from /trunk)]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Wireshark: Open Capture File

Filter: icmpv6.type == 155

home user contiki tools cooja build

Places

- Search
- Recently Used
- user
- root
- File System
- floppy0

Name	Size	Modified
external_tools_unix_04.config	98 bytes	10/01/2018
external_tools_macosx.config	2.2 kB	10/01/2018
external_tools_win32.config	1.2 kB	10/01/2018
log4j_config.xml	864 bytes	10/01/2018
quickhelp.txt	469 bytes	10/01/2018
radiolog-1538649111216.pcap	327.9 kB	10/04/2018
radiolog-1538657159714.pcap	199.2 kB	10/04/2018
radiolog-1538667350956.pcap	325.1 kB	10/04/2018
radiolog-1538759361083.pcap	542.8 kB	Saturday
radiolog-1538845172332.pcap	233.3 kB	Saturday
radiolog-1538846541178.pcap	2.0 MB	Saturday
radiolog-1539176005500.pcap	85.8 kB	Yesterday at 14:54
radiolog-1539176621614.pcap	517.7 kB	Yesterday at 15:04
radiolog-1539177130204.pcap	1.5 MB	Yesterday at 15:13
radiolog-1539180672554.pcap	545.5 kB	Yesterday at 16:11
radiolog-1539180843814.pcap	5.0 MB	Yesterday at 16:41
radiolog-1539182563304.pcap	1.5 MB	Yesterday at 16:45
radiolog-1539257068192.pcap	972.1 kB	13:26
radiolog-1539257670717.pcap	817.5 kB	13:35
radiolog-1539258387027.pcap	854.9 kB	13:47
test_template.c	3.4 kB	10/01/2018

Filter:

Filename: radiolog-1539258387027.pcap

Format: Wireshark/tcpdump/... - libpcap

Size: 854866 bytes

Packets: 9371

First Packet: 2018-10-11 13:46:27

Elapsed time: 00:01:04

☒ Enable MAC name resolution

☐ Enable network name resolution

☒ Enable transport name resolution

Cancel Open

Frame (76 bytes) 6LoWPAN

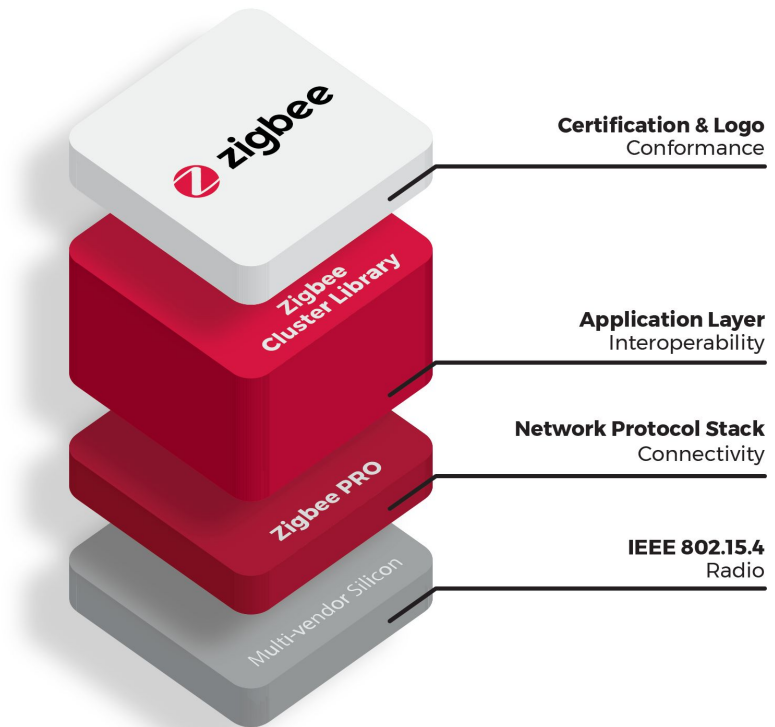
Frame (frame), 76 bytes

0000 61 dc 24 cd ab 01 00
0010 00 00 00 0c c1 7a 3
0020 aa aa 00 00 00 00 0
0030 05 12 00 80 aa aa 0
0040 00 00 00 08 06 04 0

user@instant-con... user@instant-con... [user@instant-co... rpl-daq.c (~/conti... radiolog-1539180... [ContikiRPL - Moz... Z1-simpleRPL - Co...

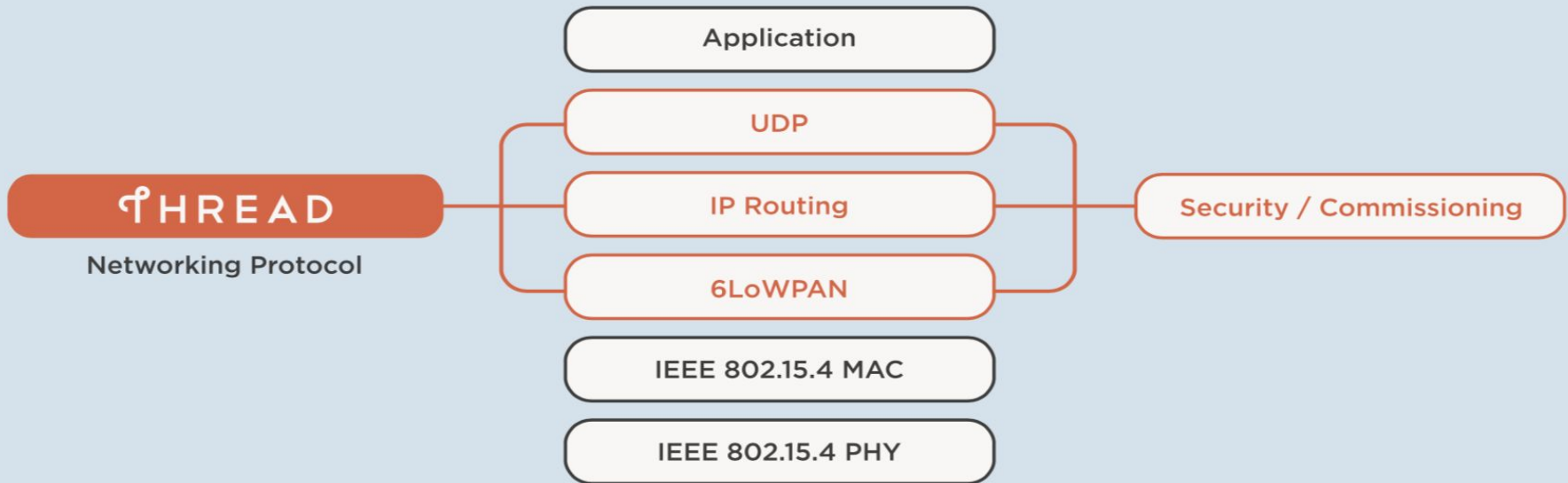
- ZigBee (ZigBee Alliance)

- Predates 6LowPAN
- It has been adapted to the new standards
- Works on 802.15.4
- Generates a mesh of nodes
- Has its own protocol stack
- ZigBee IP uses 6LowPAN



- Thread

- Specification developed for the Thread Group (ARM, Nordic, NXP, Samsung....)
- Build on top of 6LoWPAN
 - Uses *Mesh Forwarding*
- Nest has developed an open implementation: OpenThread
 - <https://github.com/openthread/openthread>



- Dotdot over Thread

- Developed for ZigBee Alliance and Thread Group
- Proposes a *lenguaje* for IoT
- Build on protocols like CoAP
- <https://www.youtube.com/watch?v=uEFyFxm-7H0&feature=youtu.be>

