BLUETOOTH® MESH

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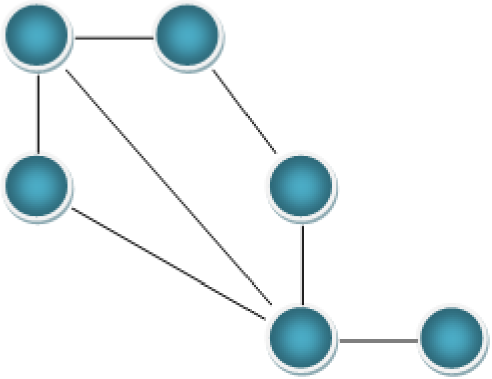
What is Bluetooth Mesh?

- New standard which came out in 2017
- Many-to-many, multi-hop topology
- No new Bluetooth HW required
- Broadcast & relay in a flooding/ripple fashion
- Mainly for signaling – not large data transfer
- Message publication & subscription
- Multi-level security
- Greatly extended range



Mesh in terms of Bluetooth

BR/EDR

for continuous connections

pairing (1:1)

audio streaming

- wireless speakers
- wireless headsets
- in-car infotainment

2016: 730M | 2020: 930M

Low Energy (LE)

for short burst connections

pairing (1:1)

data transfer

- sports & fitness devices
- medical & healthcare devices
- peripherals & accessories

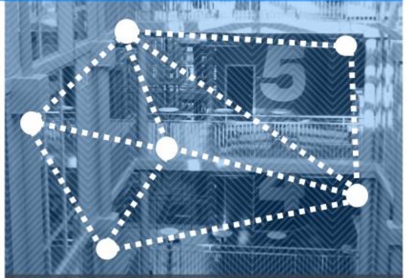
2016: 573M | 2020: 975M

broadcasting (1:m)

localized info sharing

- PoI information
- item finding
- way finding

2016: 12M | 2020: 380M



mesh networking (m:m)

large device networks

- building automation
- sensor networks
- asset tracking

Launching mid-2017

Mesh in terms of LE roles

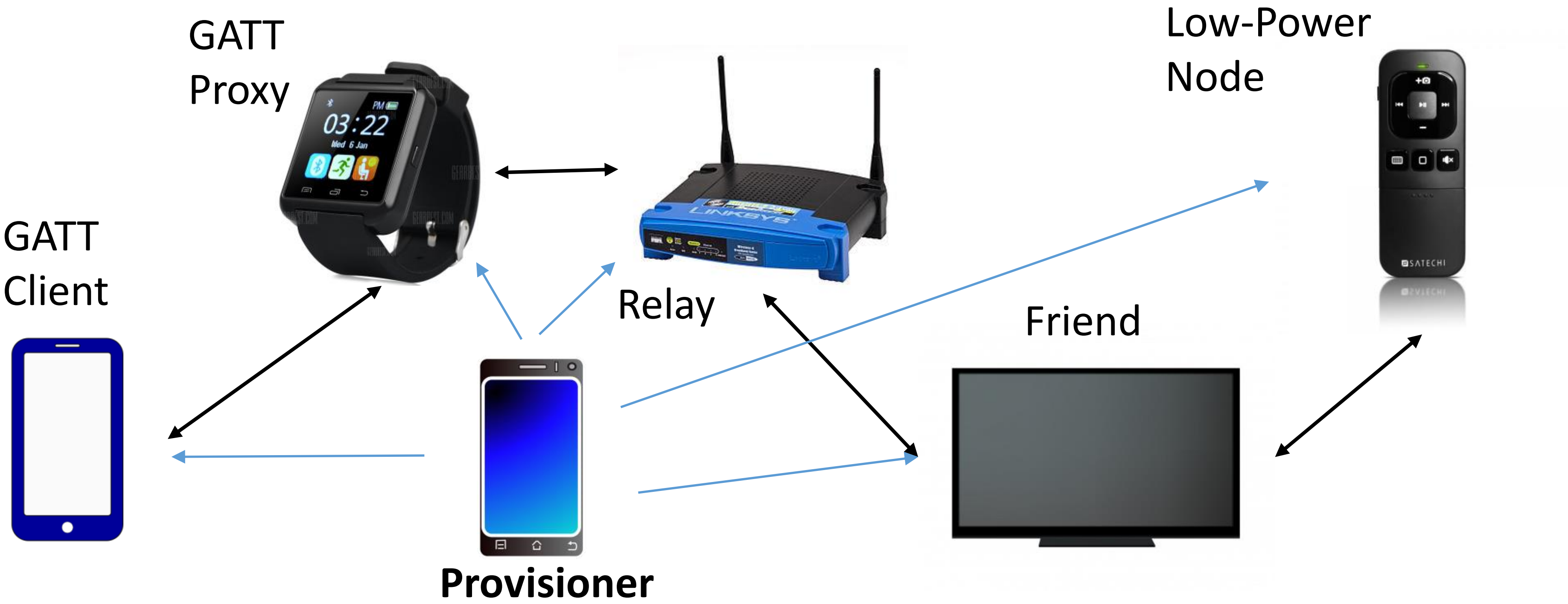
Central - Peripheral

- Connection-oriented, between two devices
- Sensor as peripheral, your phone or PC as the central

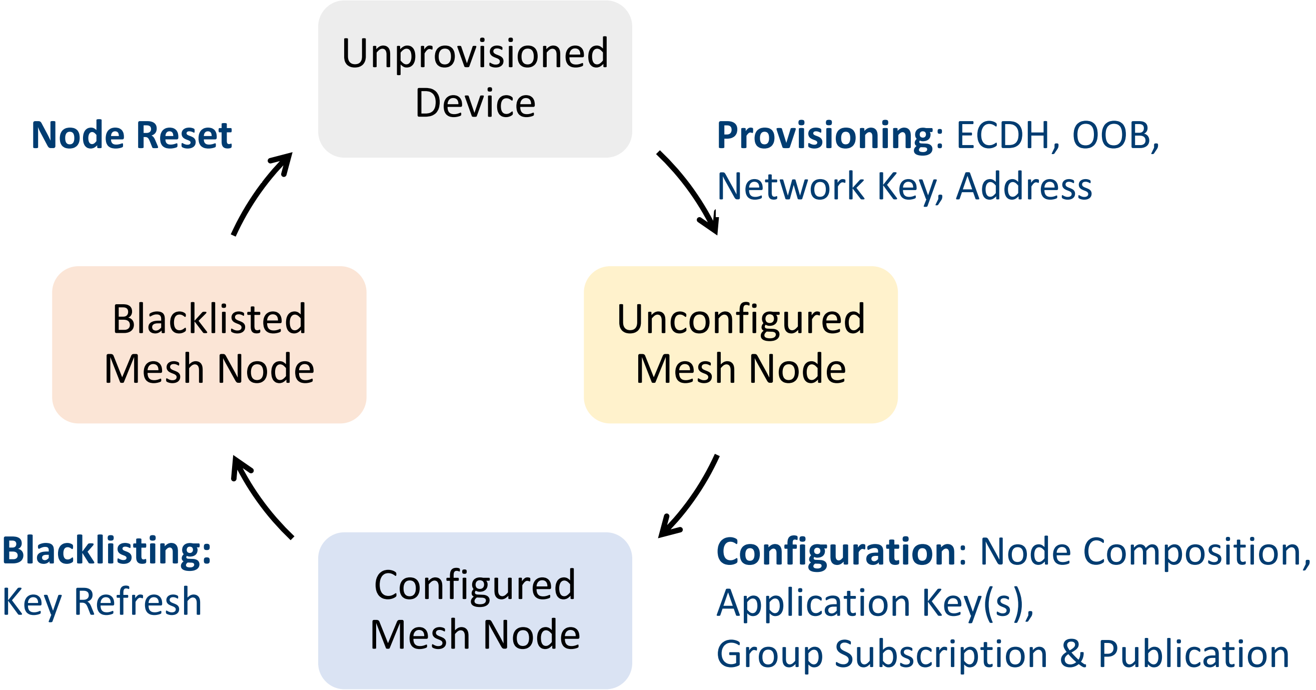
Observer - Broadcaster

- Observer scans for advertising packets
- Broadcaster sends advertising packets for everybody who is scanning
- The natural choice for Mesh

Node Types


GATT Proxy
Low-Power Node
GATT Client
Relay
Friend
Provisioner
03:22
Wed 6 Jan
LINKSYS
SATECHI

Node Lifecycle



Unprovisioned Device

Provisioning: ECDH, OOB, Network Key, Address

Unconfigured Mesh Node

Configuration: Node Composition, Application Key(s), Group Subscription & Publication

Configured Mesh Node

Blacklisting: Key Refresh

Blacklisted Mesh Node

Node Reset

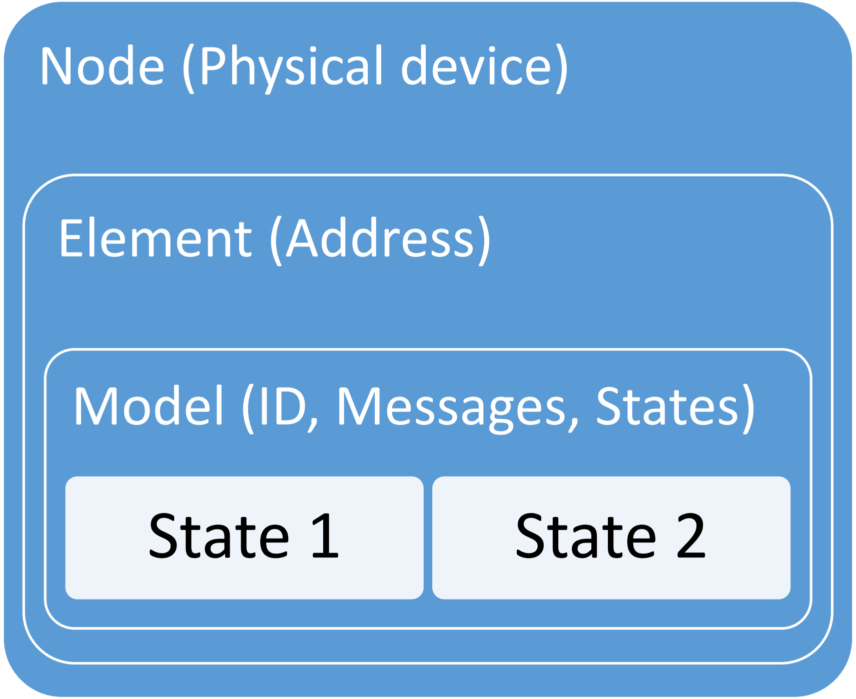
Node Composition: Elements & Models

Elements

- Unique Network Address
- Implements one or more Models

Models

- OpCode addressing
- States & Messages
- Client & Server


Node (Physical device)

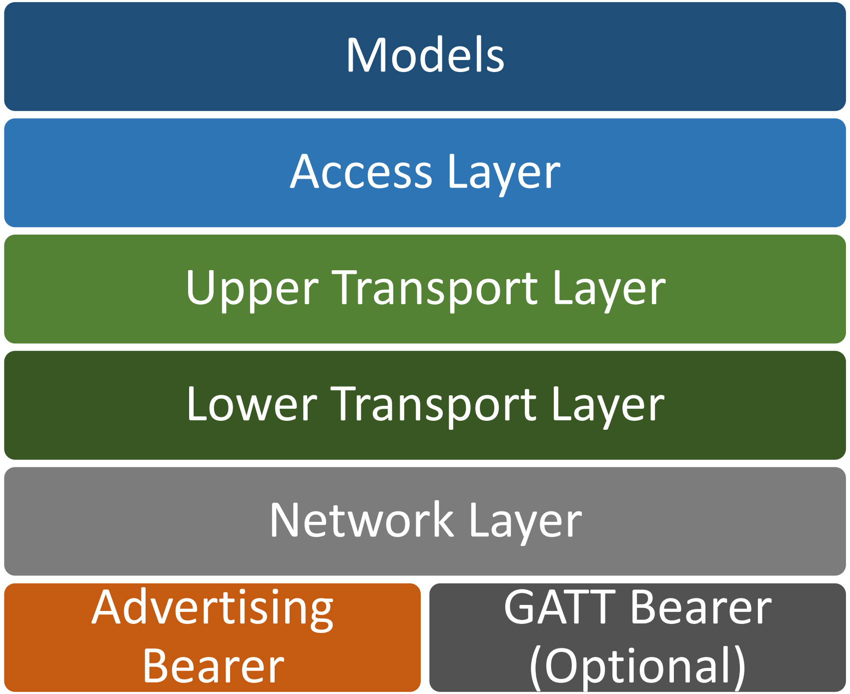
Element (Address)

Model (ID, Messages, States)

State 1

State 2

Mesh Protocol Layers



Models	states / messages / behavior
Access Layer	opcodes, multiplexing models
Upper Transport Layer	heartbeat/friendship, application encryption & authentication
Lower Transport Layer	segmentation & reassembly
Network Layer	message format, network encryption & authentication
Advertising Bearer GATT Bearer (Optional)	message transport

Anatomy of a Mesh Network PDU

IVI	NID	CTL	TTL	SEQ	SRC	DST	Transport PDU	NetMIC

Field Name	Bits	Notes
IVI	1	Least significant bit of IV Index
NID	7	Value derived from the NetKey used to identify the Encryption Key and Privacy Key used to secure this PDU
CTL	1	Network Control
TTL	7	Time To Live
SEQ	24	Sequence Number
SRC	16	Source Address
DST	16	Destination Address
TransportPDU	8 to 128	Transport Protocol Data Unit
NetMIC	32 or 64	Message Integrity Check for Network

Mesh Network Addresses

- 16-bit Network address with several categories/ranges

Unassigned	0000000000000000	No address assigned (typically used when not publishing or subscribing)
Unicast	0xxxxxxxxxxxxxxx	Every element has a unique unicast address
Virtual	10xxxxxxxxxxxxxx	Special group addresses authenticated using a 128-bit virtual label UUID
Group	11xxxxxxxxxxxxxx	Fixed (all nodes, all friends, etc) or dedicated (application specific)

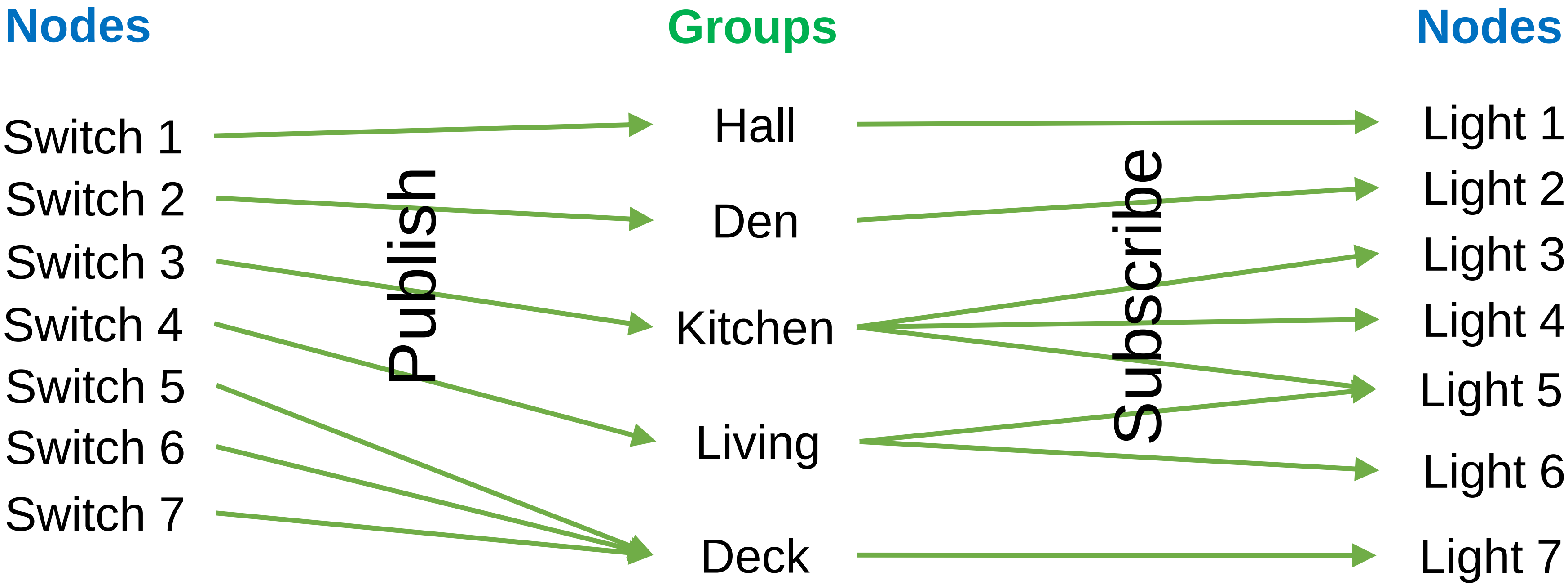
Relaying

- Time-to-Live (TTL, 7-bit, i.e. max 127)
- Decrypt with Network Key
- Decrement TTL

If TTL > 0:

- Re-encrypt with Network Key
- Send out to Network
- Application layer payload remains encrypted & untouched
  - Relay Node may not even have the Application Key

Publish & Subscribe



Nodes

Switch 1
Switch 2
Switch 3
Switch 4
Switch 5
Switch 6
Switch 7

Publish

Groups

Hall
Den
Kitchen
Living
Deck

Subscribe

Nodes

Light 1
Light 2
Light 3
Light 4
Light 5
Light 6
Light 7

Security Features

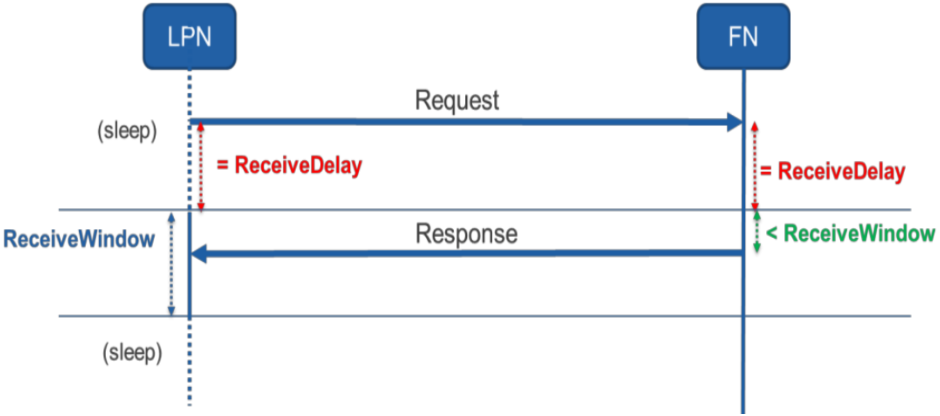
- Authentication during provisioning
- Two level encryption
  - Network
  - Application
- Replay protection
  - IV Index (32-bits)
  - Sequence number (24 bits)
  - IV Index Update procedure
- Key Refresh
  - Node Blacklisting

Segmentation & Reassembly

- A message can be either unsegmented or segmented
- Payload
  - Unsegmented: 15 bytes
  - Segmented: 12 bytes per segment, max 32 segments = 384 bytes
  - Contains 4 or 8 byte MIC at the end, reducing usable payload size
- Unsegmented messages are inherently unreliable
- Segments of a segmented message are acknowledged by the receiver
  - One-segment “segmented” message can be used for reliable sending

Friendship

- 100% duty-cycle scanning needed for reliability, but consumes a lot of power
- Mix of battery & mains powered nodes
- Solution: pair up stable power supply nodes (Friends) with Low Power Nodes (LPNs)
- Friends queue up messages for the LPN
- LPN queries the Friend periodically if there are any messages for it



IMPLEMENTATION STATUS & PLANS

Support in Zephyr* OS

- Available starting with Zephyr 1.9
- All mandatory features implemented
- Tested against multiple other implementations
- Ported to MyNewt
  - Multiple valuable fixes ported back to Zephyr
- Demos possible with many popular supported Zephyr boards
  - Come to the Zephyr booth to see it in action!
- Minimum RAM footprint (entire OS with Mesh) is ~12kB
  - Fits even the most constrained 16k boards, like BBC micro:bit

*Other names and brands may be claimed as the property of others.

Support in Linux*

- meshctl tool released with BlueZ 5.47
  - GATT Client
  - PB-GATT Provisioner
- Ongoing work both in user space (BlueZ) and kernel
  - Advertising & Scanning managed in the kernel
    - Controlled through mgmt API extensions
  - Essentially everything else in a user space meshd

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Future development

- Mesh Vendor HCI Extensions
  - Supported both by Linux & Zephyr
- More features
  - Friend support for Zephyr
- More standard models
- More demos with various boards

QUESTIONS?

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