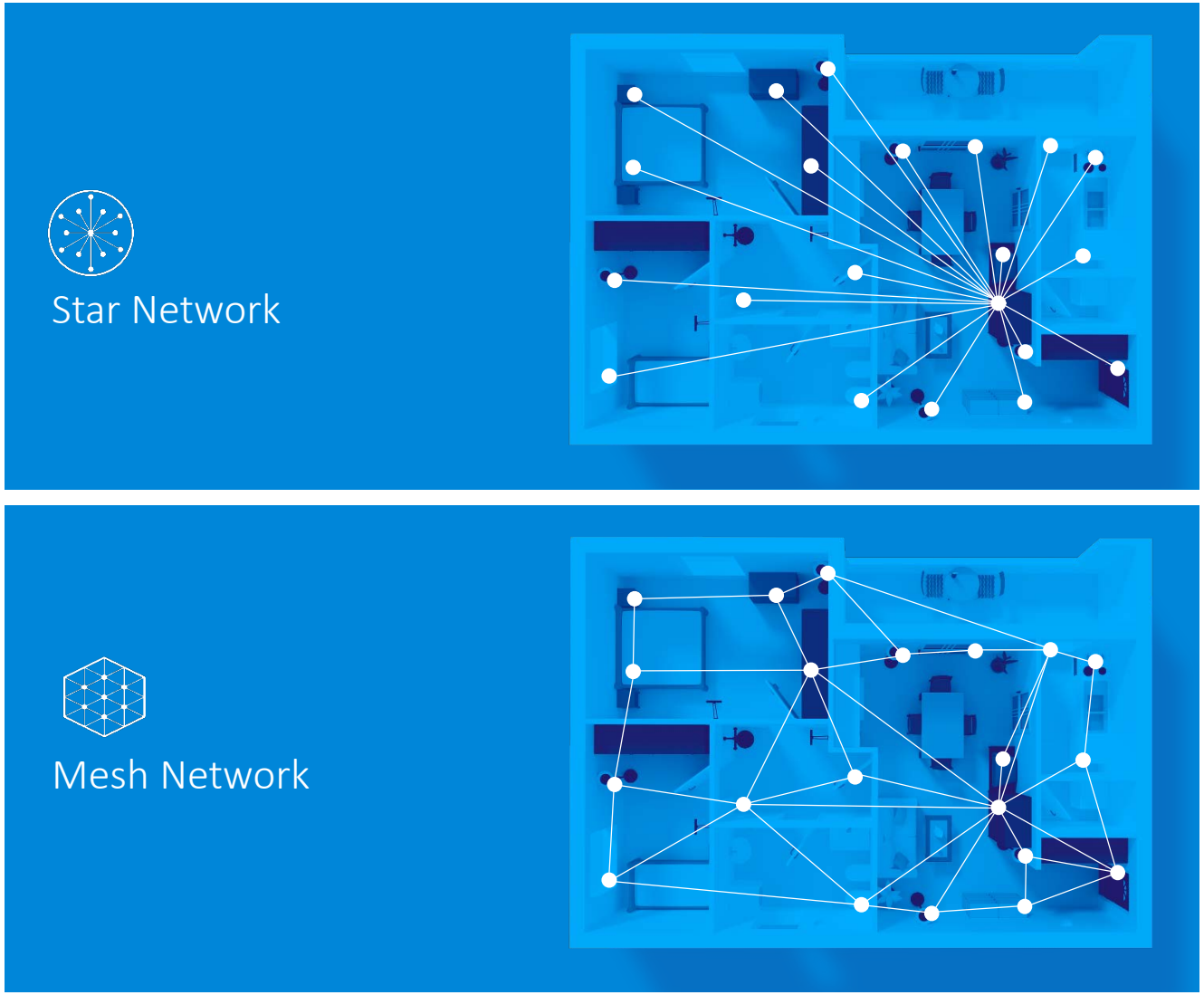
SILICON LABS

# Unraveling Mesh Networking Options

TOM PANNELL | 28 FEBRUARY 2018

# The Benefits of Mesh Networks




- **Extend the range** of connections from gateways or mobile devices with multi-hop communication
- **Reduce power consumption** in a system with shorter transmission distances between devices
- **Increase system scale** by supporting hundreds of devices in a single subnet
- **Improve system reliability** with self-healing networks that overcome node failures
- **Deliver optimal responsiveness** with device to device communication

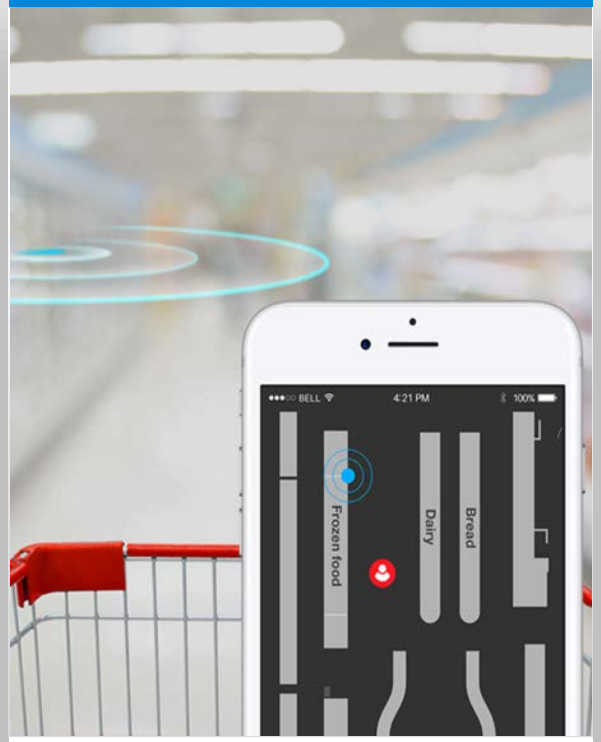
# Applications for Mesh Networking

## HOME & BUILDING AUTOMATION

Scale system deployment

Support device-to-device communication

## BEACONING

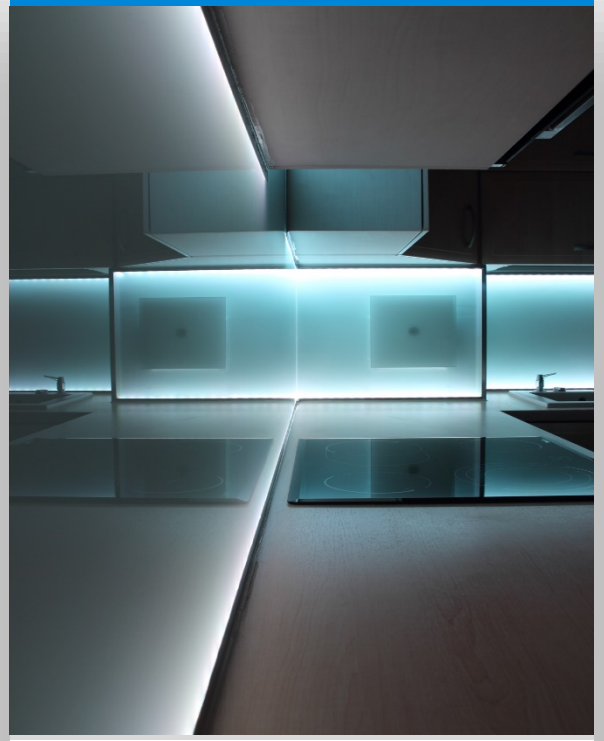



Simplify beacon management

Deliver location services

Increase beacon service range

## LIGHTING



Deliver instant response to switch actions

Provide advanced lighting control

Integrate functionality

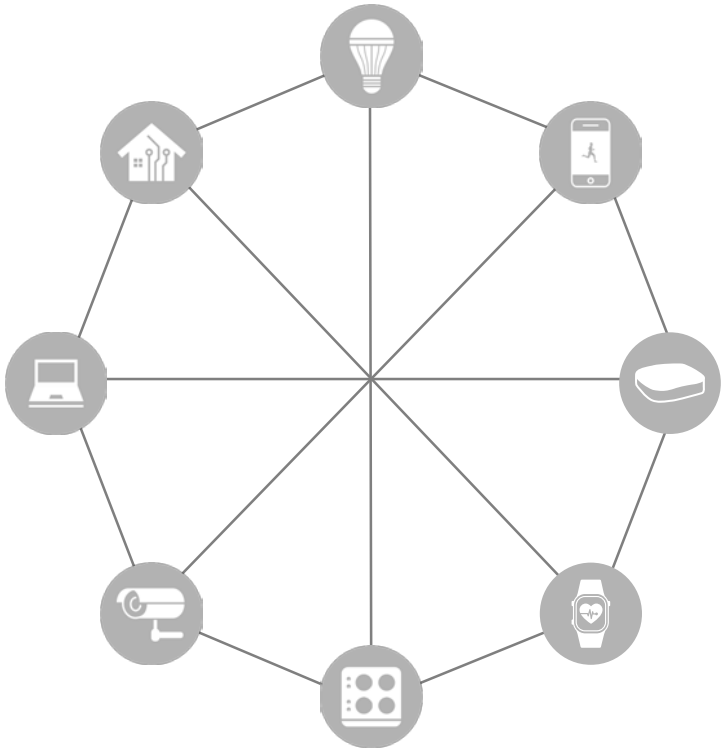
## ASSET TRACKING

Eliminate manual scanning

Determine location in real-time

Simplify beacon deployment

# Selecting your Connectivity and the Role of Ecosystems



amazon alexa · HomeKit · Google Home · Microsoft Azure · COMCAST

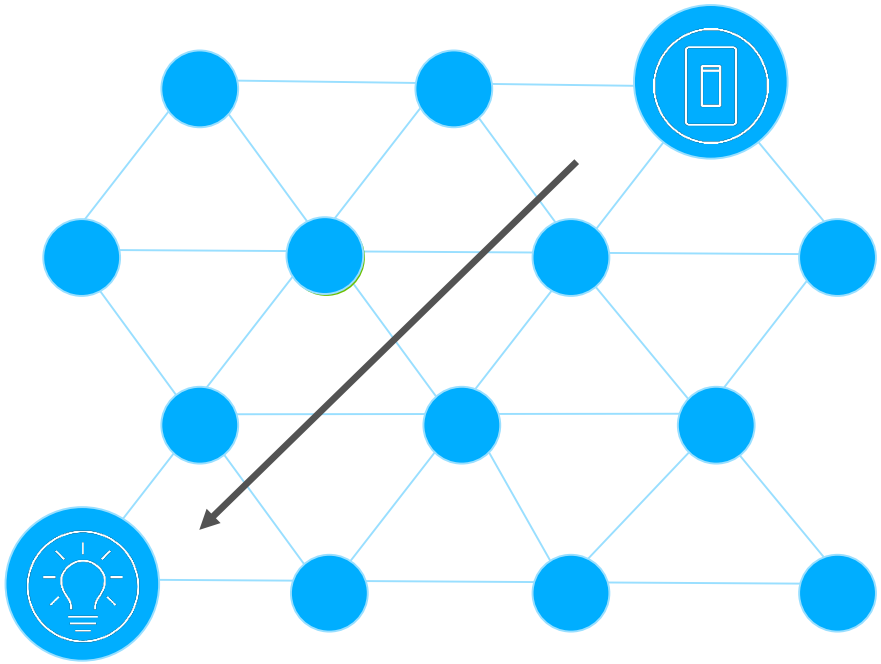
Deutsche Telekom · Tencent 腾讯 · mi · Alibaba Group 阿里巴巴集团

- Identify key ecosystems
- Specify device application layer needs
- Performance requirements
- Determine IP connectivity importance

# Mesh Networking Technology Comparison

| | Bluetooth Mesh | Thread | Zigbee |
|---|---|---|---|
| Market Focus | Home Automation, Lighting, Building Automation | Home Automation, Lighting, Building Automation | Home Automation, Lighting, Building Automation, Metering |
| Application Layer | Native Mesh Model | Any IP based Application Layer (e.g. Dotdot, OCF, Weave) | Dotdot / Zigbee Cluster Library (ZCL)", ZCL is inclusive of HA and SE |
| IPv6 | No | Yes | No |
| Cloud Connectivity | Smartphone (temporary) Gateway | Border Router Gateway | Gateway |
| Ecosystems | None | Nest | Service Providers (e.g. Comcast, Deutsche Telekom), Samsung SmartThings |
| Routing | Managed flooding | Full Routing | Full Routing |
| Additional Notes | Beaconing, Direct phone connectivity | | Most mature |

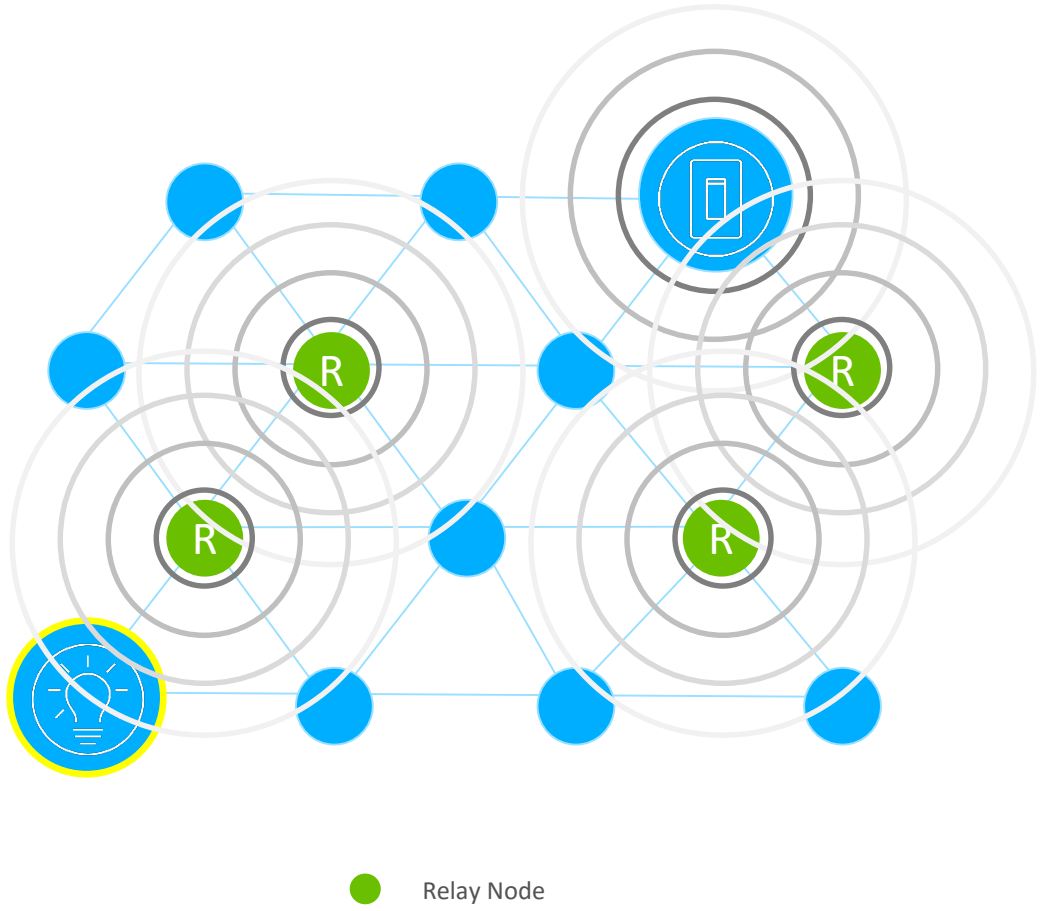
# Managed Flood Messaging



## Managed flood message relay

- Time to live message counter
- Message cache
- Relay function optional

# Managed Flood Messaging

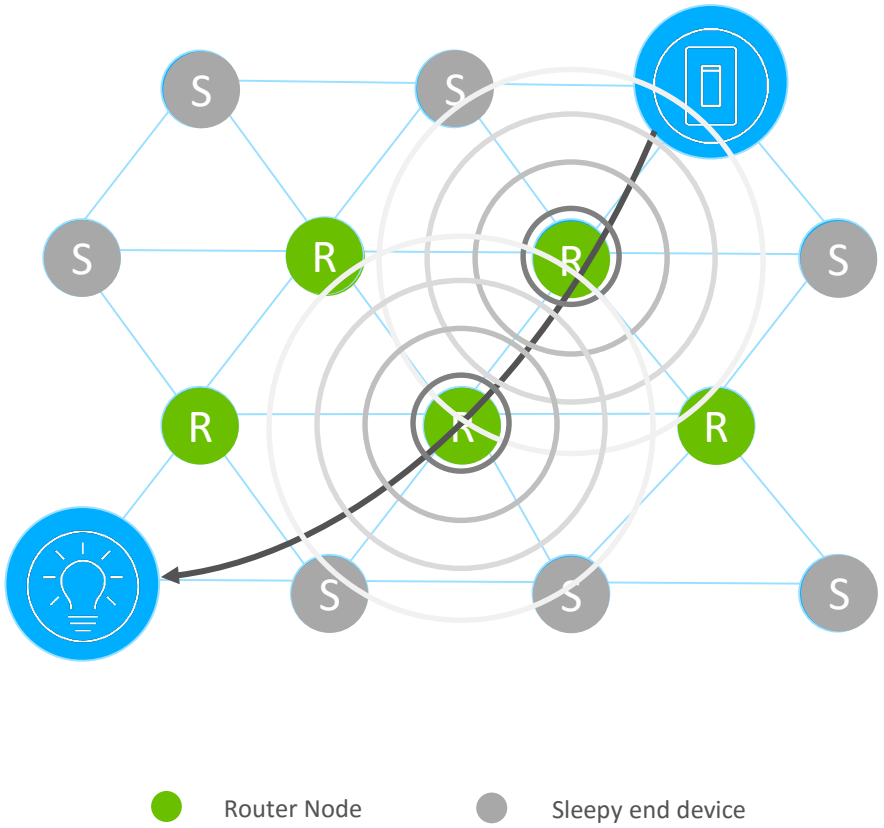



## Managed flood message relay

- Time to live message counter
- Message cache
- Relay function optional

  R = relay function turned on

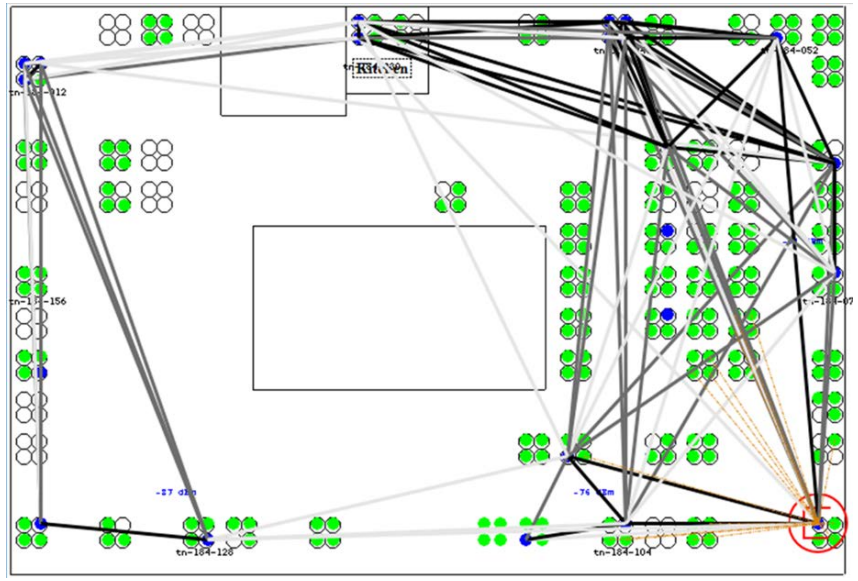
# Full Routing Messaging

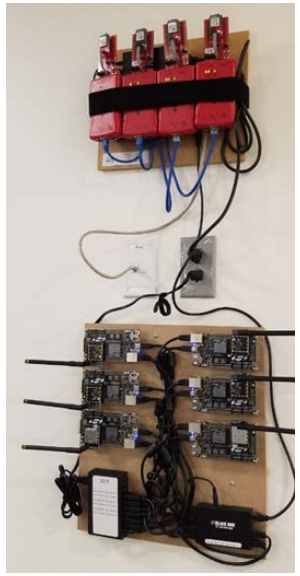



## Routing based messaging

- Coordinator
- Router nodes
- Sleepy end devices

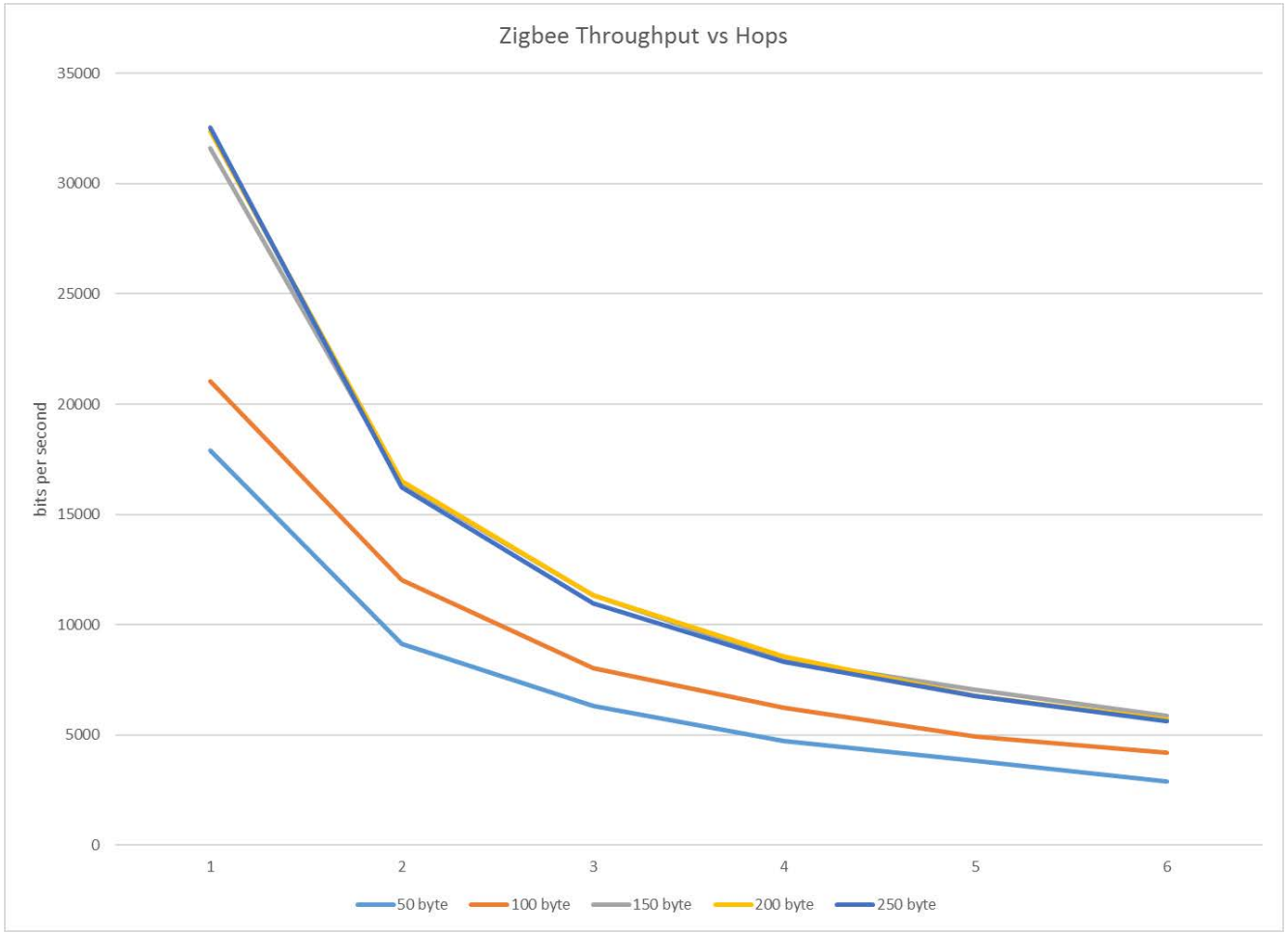
# Measuring Mesh Network Performance





- Performance measures include throughput, latency, and reliability
- Subject to real-world conditions such as Wi-Fi® networks and normal interference
- Ethernet backchannel and packet tracing across all nodes provides deeper analysis
- Energy measurements correlated with wireless traffic provide additional system characteristics

# Throughput Variations as a Function of Payload Size and Network Hops

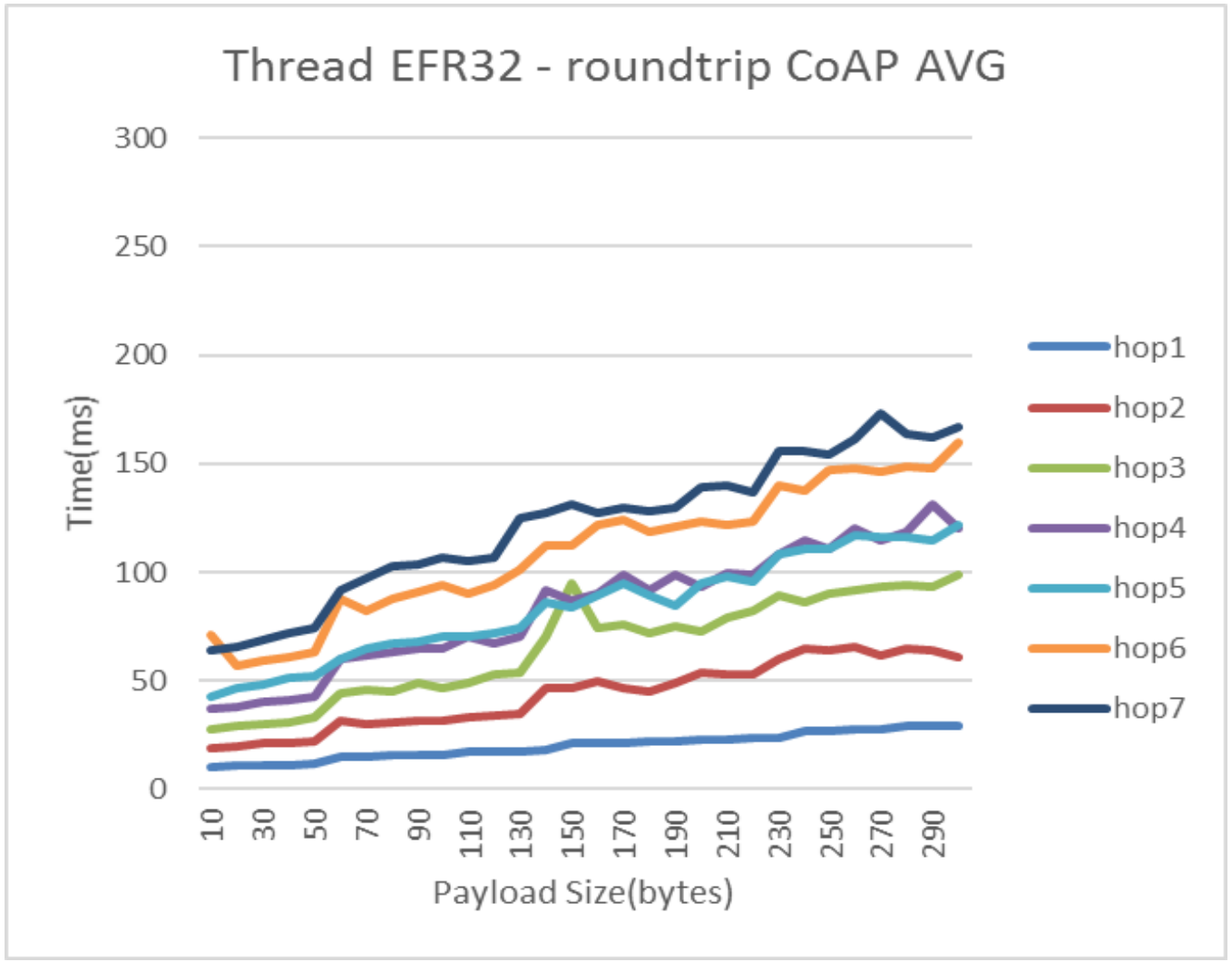



- Measure round trip over multiple hops with different application payloads
- Provides indication of amount of traffic the network can sustain
- Test executed for each protocol on different chips
- 1 hop provides the best performance
- Throughput levels out at 5-6 hops
- Throughput increases as payload increases to some limit

# Throughput Comparison for Protocols for 100 Byte Payload

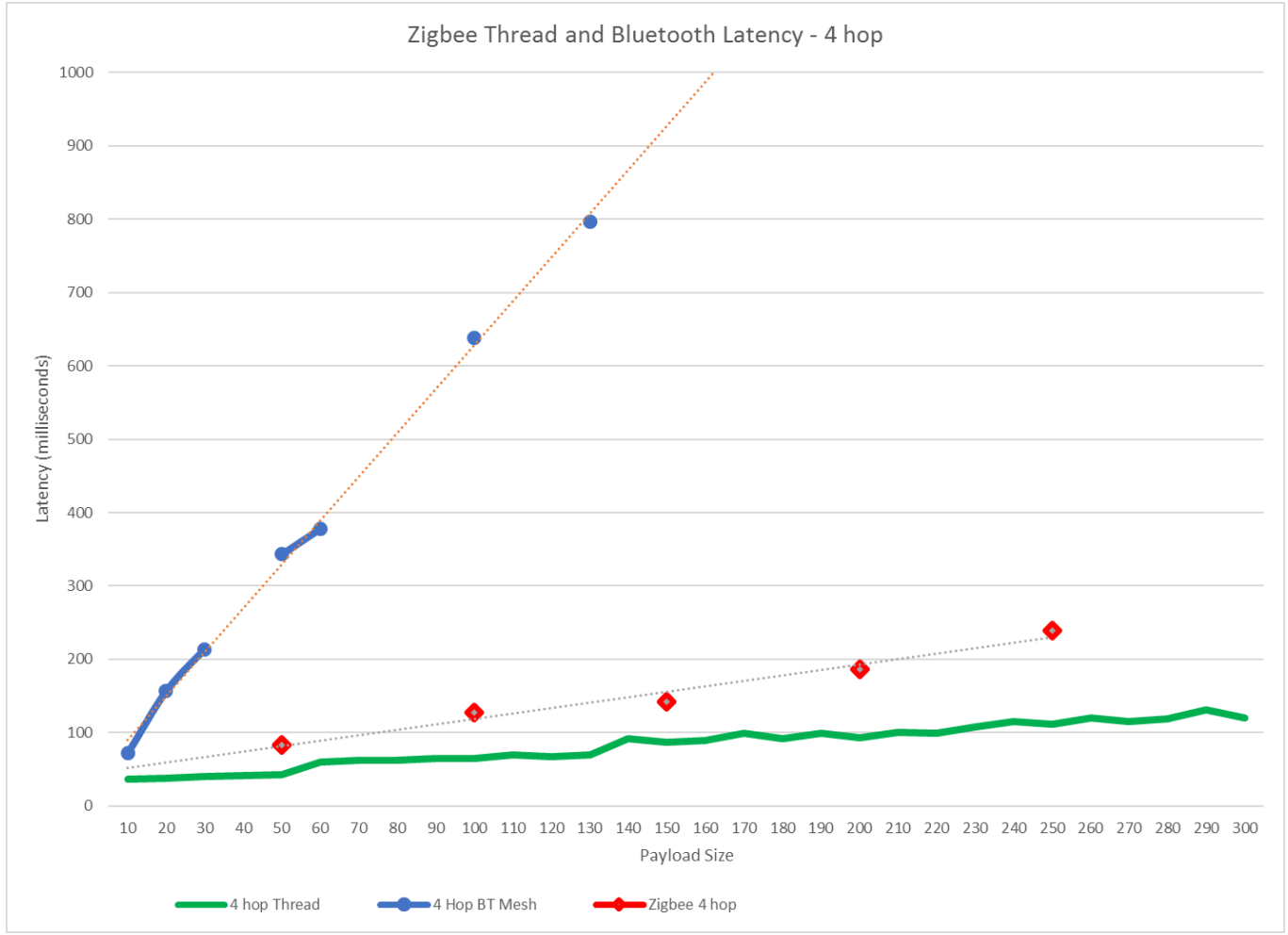

- Typical networks are 2 to 3 hops
- Throughput varies based on number of hops
  - ~24000 bits per second 1 -2 hops on Thread
- As number of hops increases protocol performance becomes similar
- Small packet payload for Bluetooth mesh results in reduced throughput

# Latency Variations as a Function of Payload Size and Network Hops



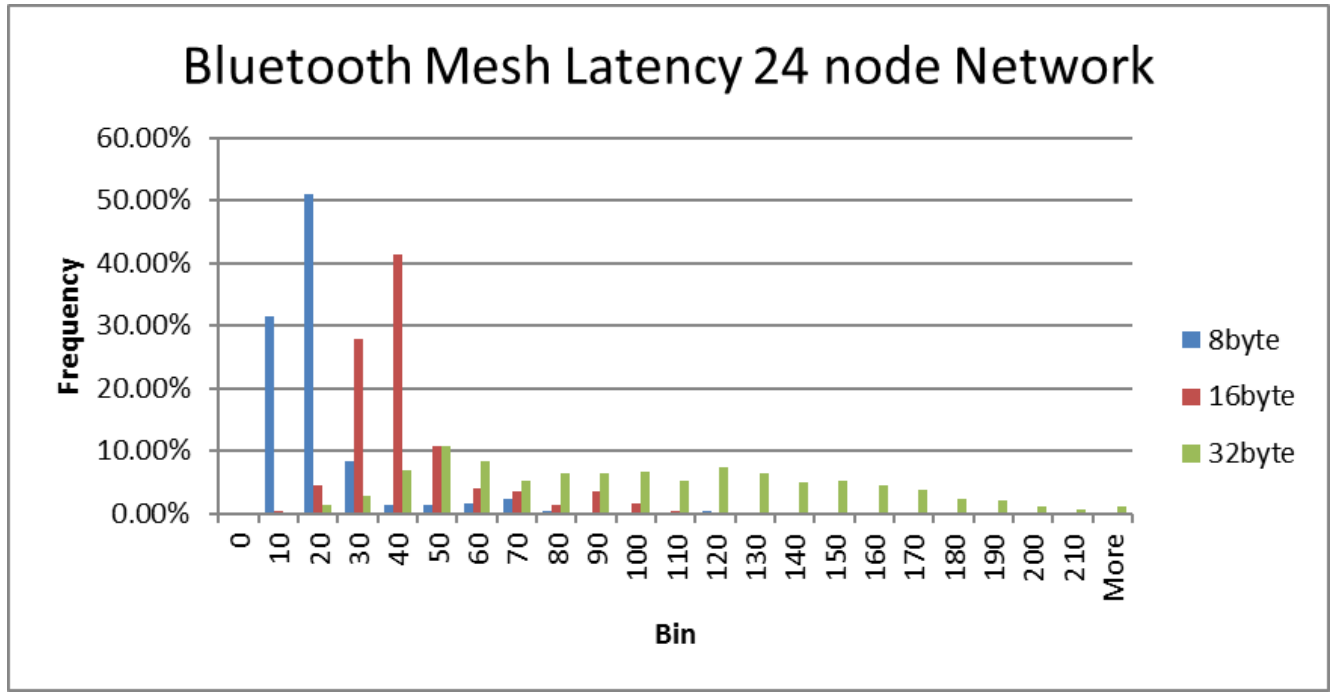

- Measure roundtrip latency over multiple hops with different application payloads
- Provides comparative data on what latency can be achieved versus number of hops
- Test executed for each protocol on different chips
- Can see fragmentation of payload into different packets
  - Varies by protocol
  - For Thread you see fragmentation affect at 60 bytes

# Latency Comparison for Protocols Over 4 Hops



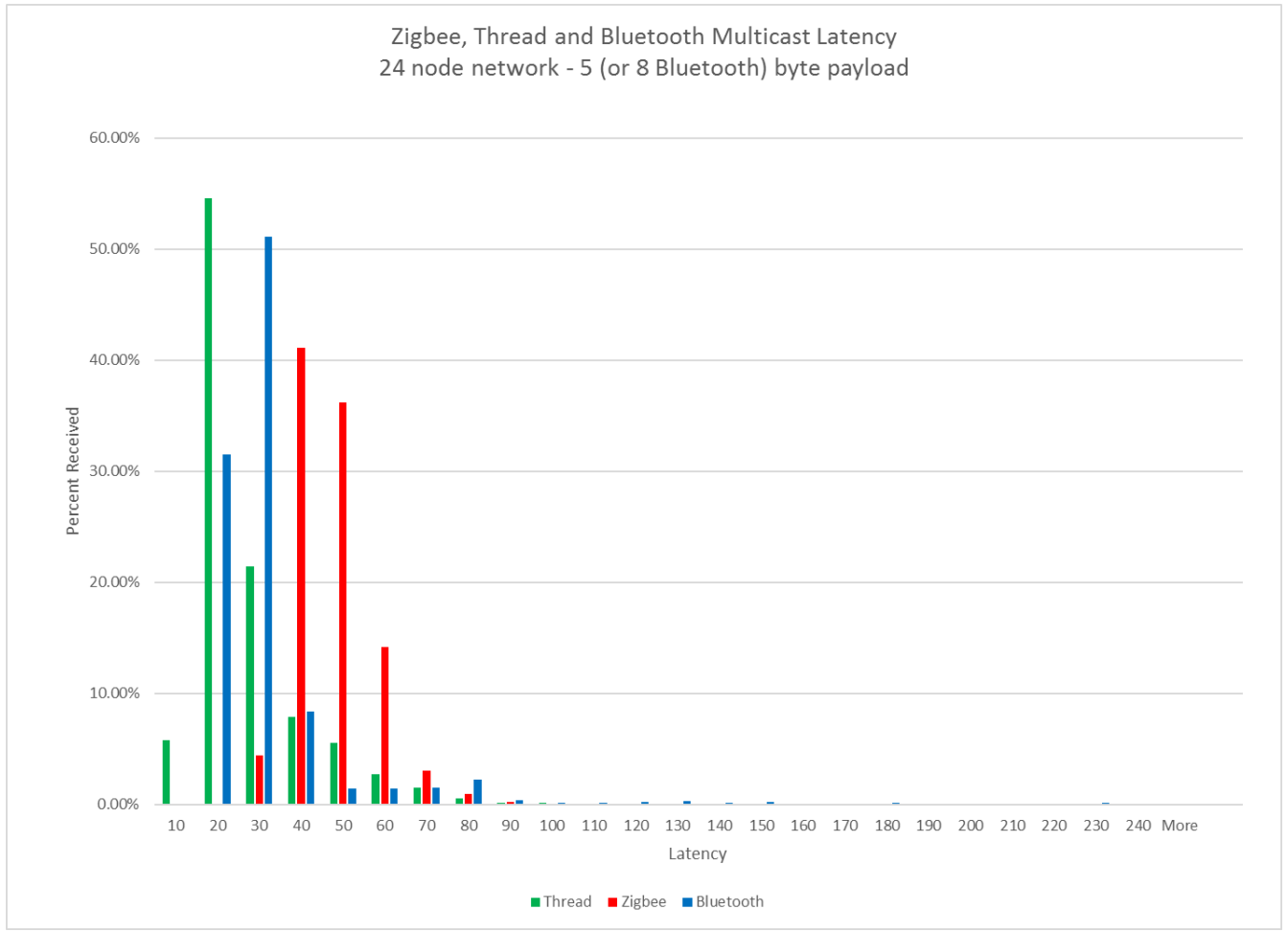

- Protocols provide similar latency for very small payloads
- Thread fragmentation (6LowPAN) has the best efficiency and latency performance as payload size increases
- Zigbee has good efficiency but some application layer fragmentation
- Bluetooth mesh latency degrades as payload size increases due to small packet size and resulting segmentation

# Reliability and Latency in Large Multicast Network



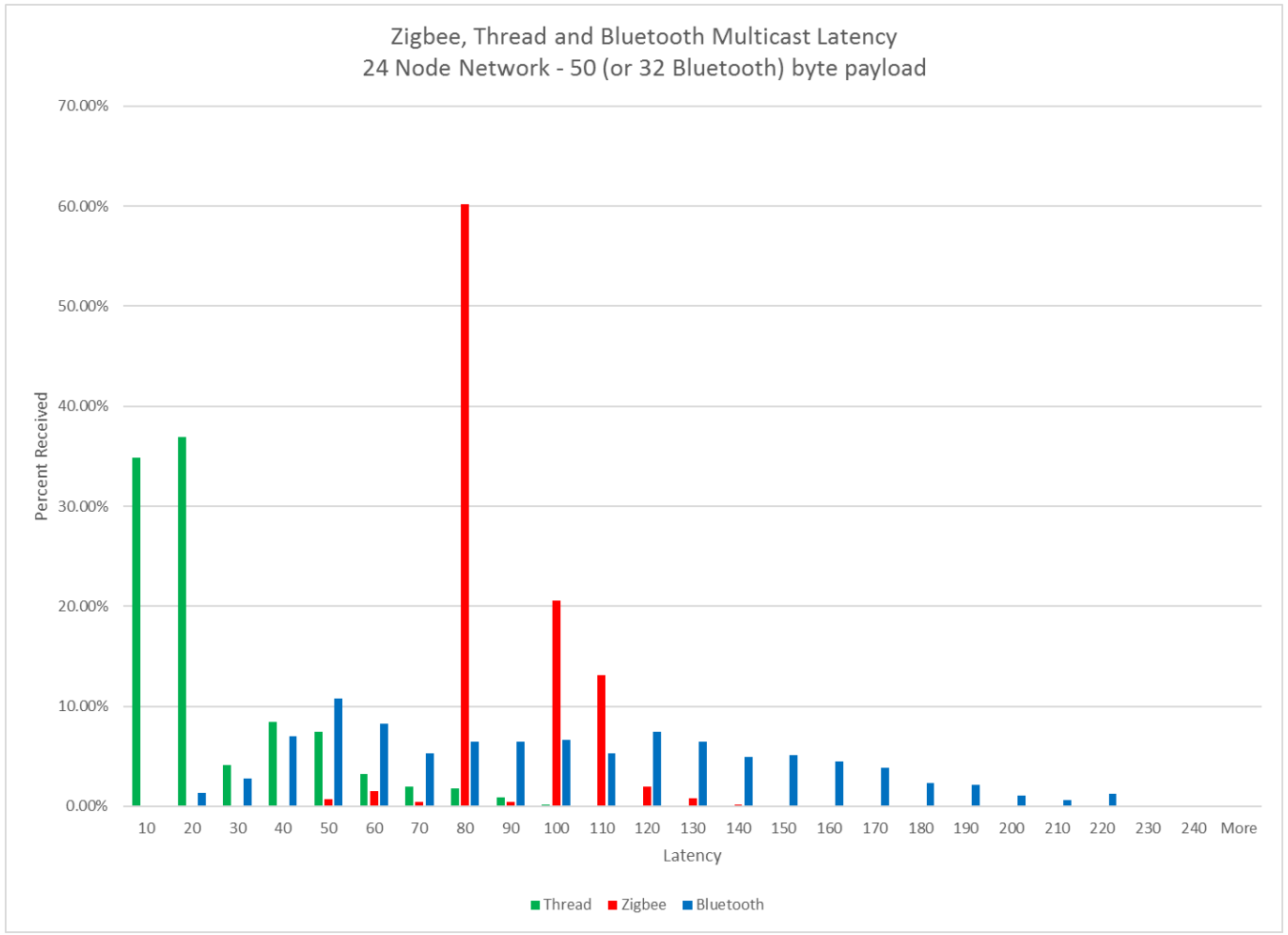

- Open air testing – network sets itself up and determines number of hops
- Run multicast testing of different network sizes:
  - 24 devices
  - 48 devices
  - 96 devices
  - 144 devices
  - 192 devices
- Evaluate different payload sizes
- Evaluate scalability, reliability and latency as network size increases

# Small Network with Small Payload Multicast Comparison



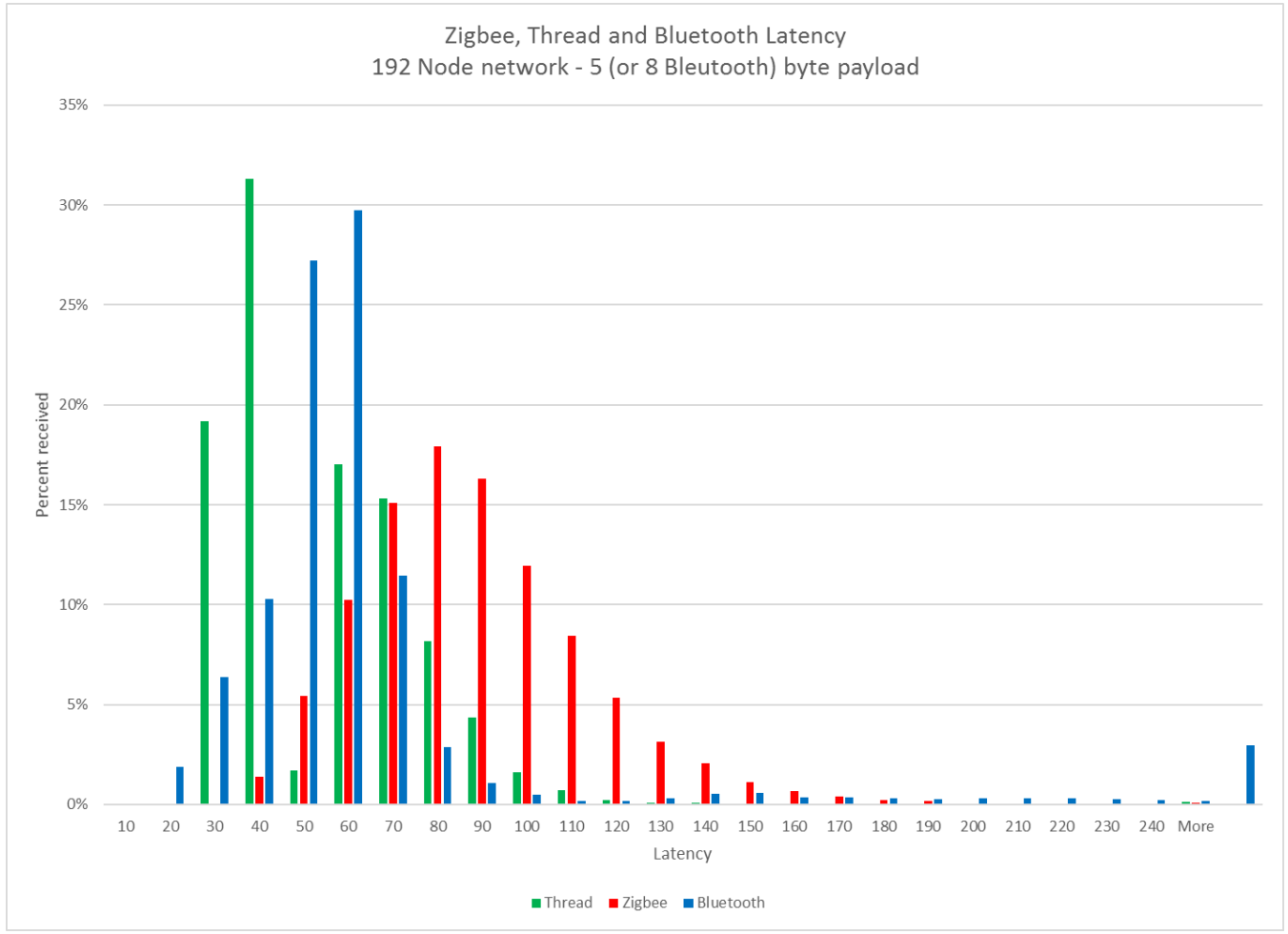

- 24 node network with 5 byte payload (Zigbee, Thread) and 8 byte (Bluetooth)
- All protocols perform well - under 100 milliseconds to receive nearly all messages
- All protocols provide very good reliability

# Small Network with Moderate Payload Multicast Comparison



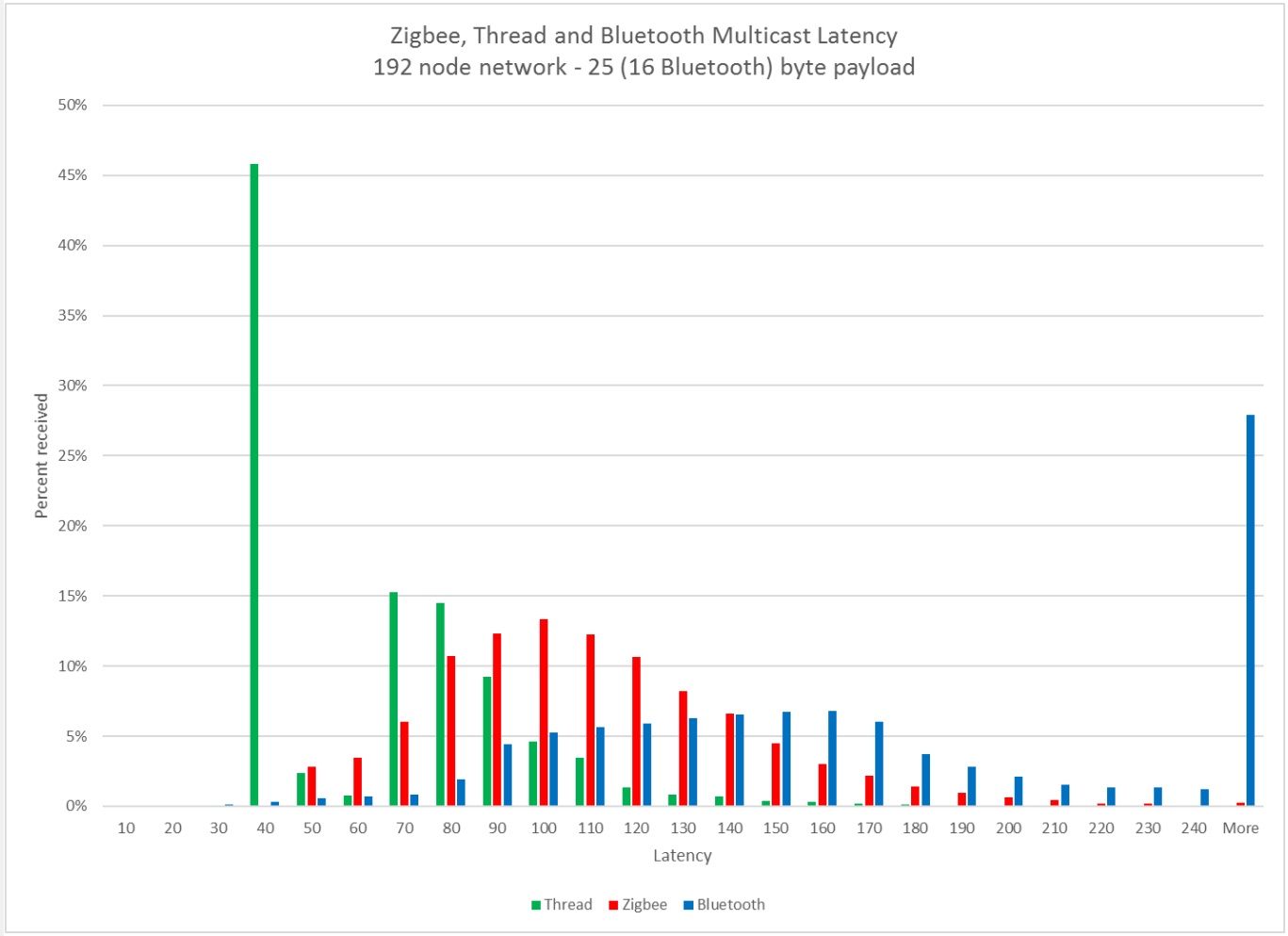

- 24 node network with 50 byte payload (Zigbee, Thread) and 32 byte (Bluetooth)
- Thread performs the best with latency spreading up to 100 ms
- Zigbee performs well with most packets received with 80 ms latency but spreading up to 130 ms
- Bluetooth mesh latency has the greatest variation in latency performance, spreading across 20 ms to 200 ms

# Large Network with Small Payload Multicast Comparison




- 192 node network with 5 byte payload (Zigbee, Thread) and 8 byte (Bluetooth)
- Thread performs the best with latency spreading up to 100 ms
- Zigbee performs well with most packets received with 80 ms latency but spreading up to 130 ms
- Bluetooth mesh latency peaks at 60 ms and most under 100 ms. Spreading goes over 200 ms with 3% over 250 ms

# Large Network with Moderate Payload Multicast Comparison




- 192 node network with 25 byte payload (Zigbee, Thread) and 16 byte (Bluetooth)
- Thread performs the best with latency spreading up to 120 ms
- Zigbee performs well with peak at 100 ms but spread to 200 ms
- Bluetooth spreading from 90 to 180 ms and large % delivery over 250 ms

# Performance Summary Comparison

- Ecosystems will drive protocol choices for end device makers
- Different protocols have different performance characteristics
- One protocol cannot fit requirements for all scenarios and it is important to understand the underlying performance for a particular use and topology
- With small networks and small payloads Thread, Zigbee and Bluetooth mesh perform similarly
- As payload size increases, Bluetooth mesh performance degrades the most, due to smaller packet sizes
- As network size increases relay selection becomes important
  - Latencies increase for all protocols but Bluetooth mesh sees larger increases due to congestion from flooding
  - Bluetooth is designed to allow installer to reduce number of relay nodes to reduce flooding

# Silicon Labs Multiprotocol Wireless Solutions

- Expertise: 15+ years providing wireless mesh solutions with over 150 million deployed nodes
- Flexibility: The widest range of solution offerings from certified modules to multiprotocol SoCs
- Productivity – Patented advanced network analysis, energy profiling and application configuration

[silabs.com/mesh-networking](silabs.com/mesh-networking)


www.silabs.com

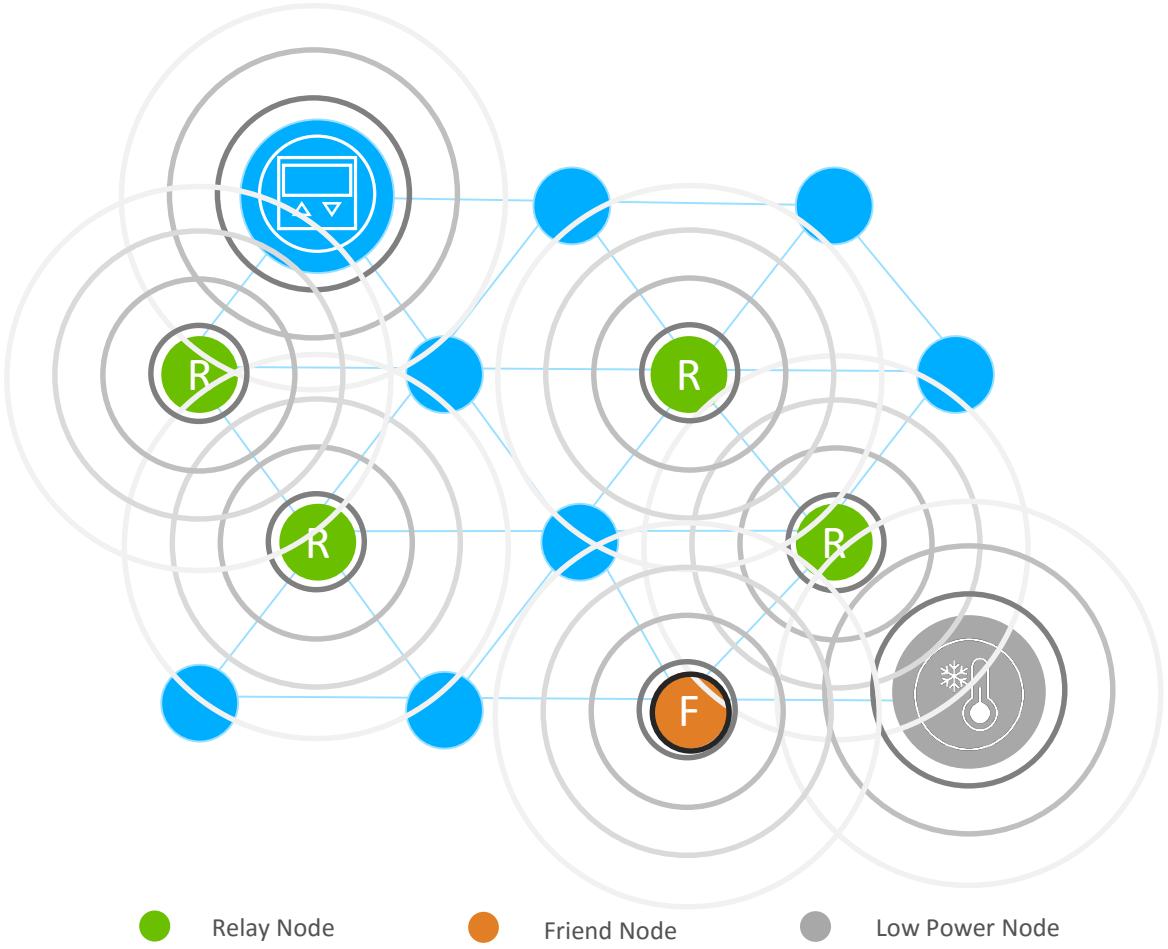
# Back-up

# Device Support in Protocols and Related Application Layers

| | Bluetooth Mesh | Thread | Zigbee |
|---|---|---|---|
| Application Layer(s) | Native – Mesh Model | IP Based<br>e.g. Dotdot, OCF, Weave | Dotdot, ZCL, HA, SE |
| Lighting | +++ | +++ | +++ |
| Home Security | - | +++ | +++ |
| Home Automation | + | +++ | +++ |
| Building Automation | + | +++ | +++ |
| Metering | - | +++ | +++ |
| Beaconing | + | - | - |

| | |
|---|---|
| +++ | Comprehensive |
| ++ | Extended |
| + | Limited |
| - | Not Natively Supported |

# Managed Flood Messaging




## Managed flood message relay

- Time to live message counter
- Message cache
- Relay function optional
- Low power nodes find friends

R = Relay function on
F = Friend function on
● = Low power function on