Smart Body Area Network Workshop, ETSI

Mesh network technologies for industrial applications

Oct. 2018

TOSHIBA

Ichiro Seto, Deputy Managing Director
Toshiba Research Europe Ltd.,
Telecommunications Research Laboratory

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01

Introduction to TREL

TREL, Toshiba Research Europe Limited,

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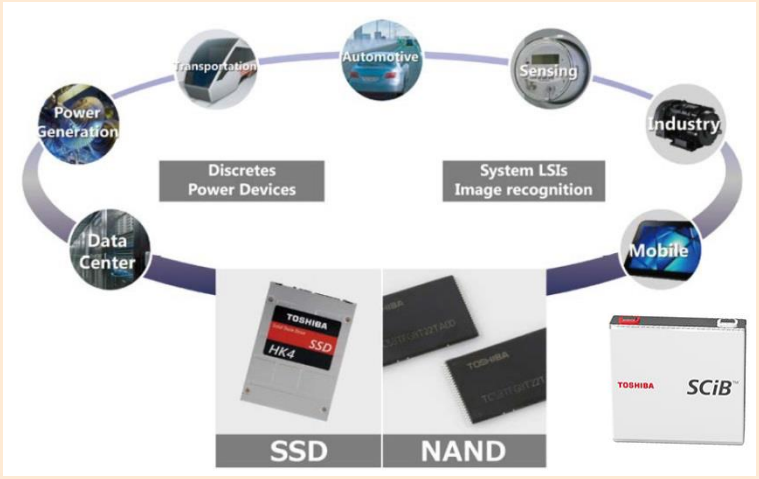
What is Toshiba Corp. doing in Business

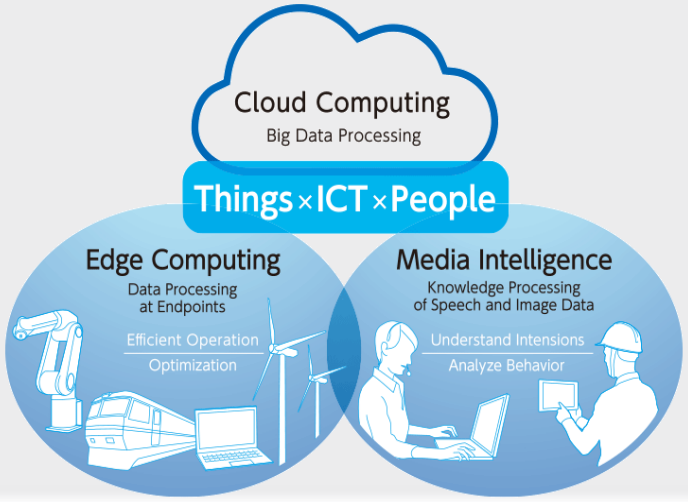
Infrastructure system

Energy system

Semiconductor Supplier



Industrial IOT solutions



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Corporate Research and Development

R&D Structure in Japan and Overseas has covered wide-range Biz portfolio

Toshiba Software (India) Private Limited

Toshiba Software Development (Vietnam) Co., Ltd.

Toshiba (China) Co., Ltd. Research and Development Center

Toshiba America Research, Inc.

Toshiba Electronics Europe GmbH

Toshiba America Electronic Components, Inc.

Toshiba Research Europe Ltd. (Cambridge)

- Cambridge Research Laboratory
- Telecommunications Research Laboratory

Corporate-level Research centers

- Corporate Research & Development Center
- Corporate Manufacturing Engineering Center
- Power and Industrial Systems Research and Development Center

Development Centers of in-house Companies

- IoT Technology Center
- Power and Industrial Systems Research and Development Center
- Center for Semiconductor Research & Development

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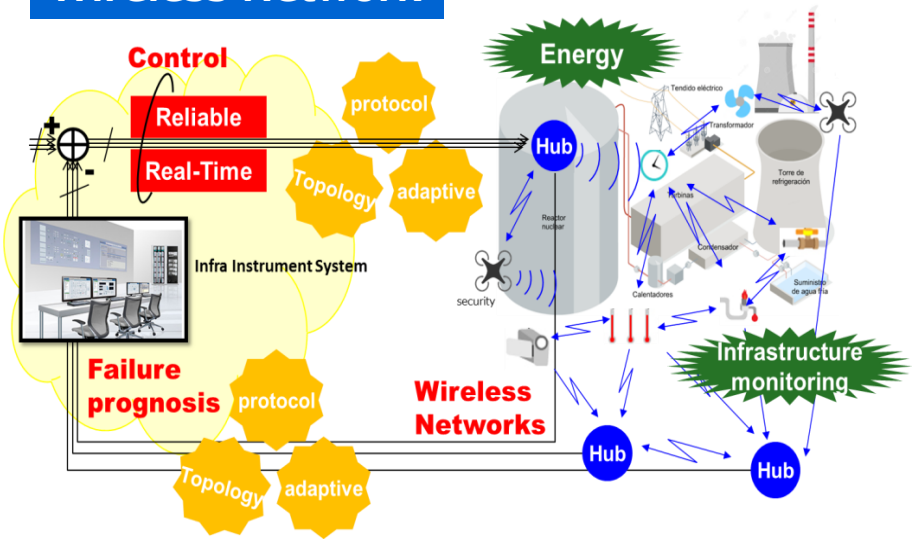
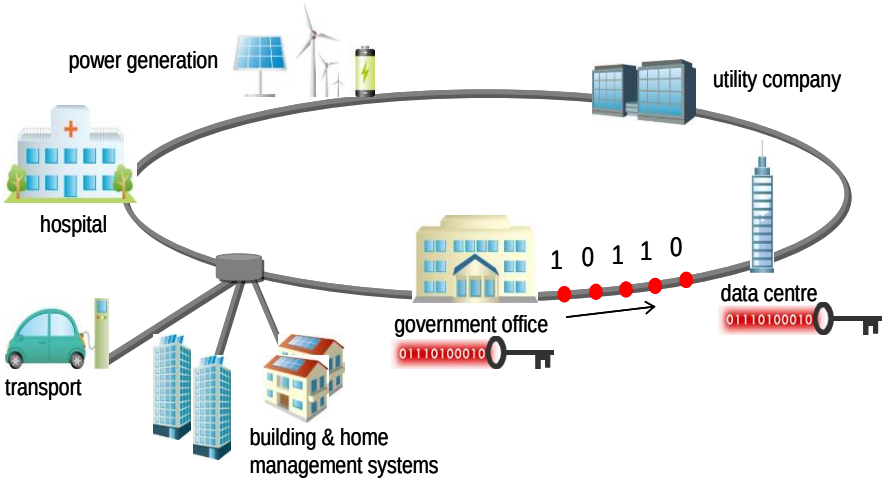
TREL activities in Bristol and Cambridge

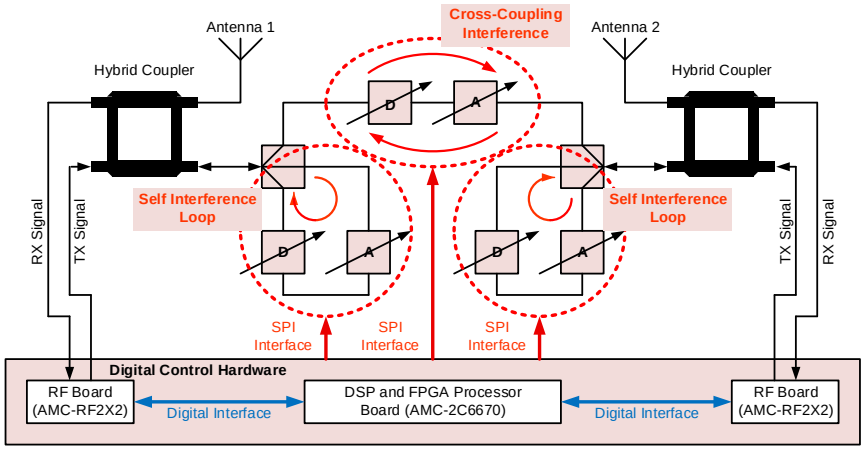
Wireless Network



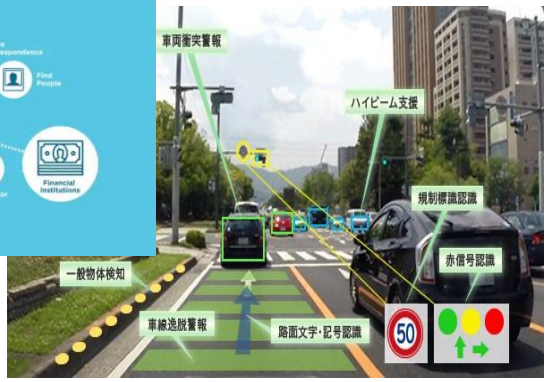
Quantum Information



Signal Processing



AI for Speech and Video recognition



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02

Wireless Network beyond industry 4.0

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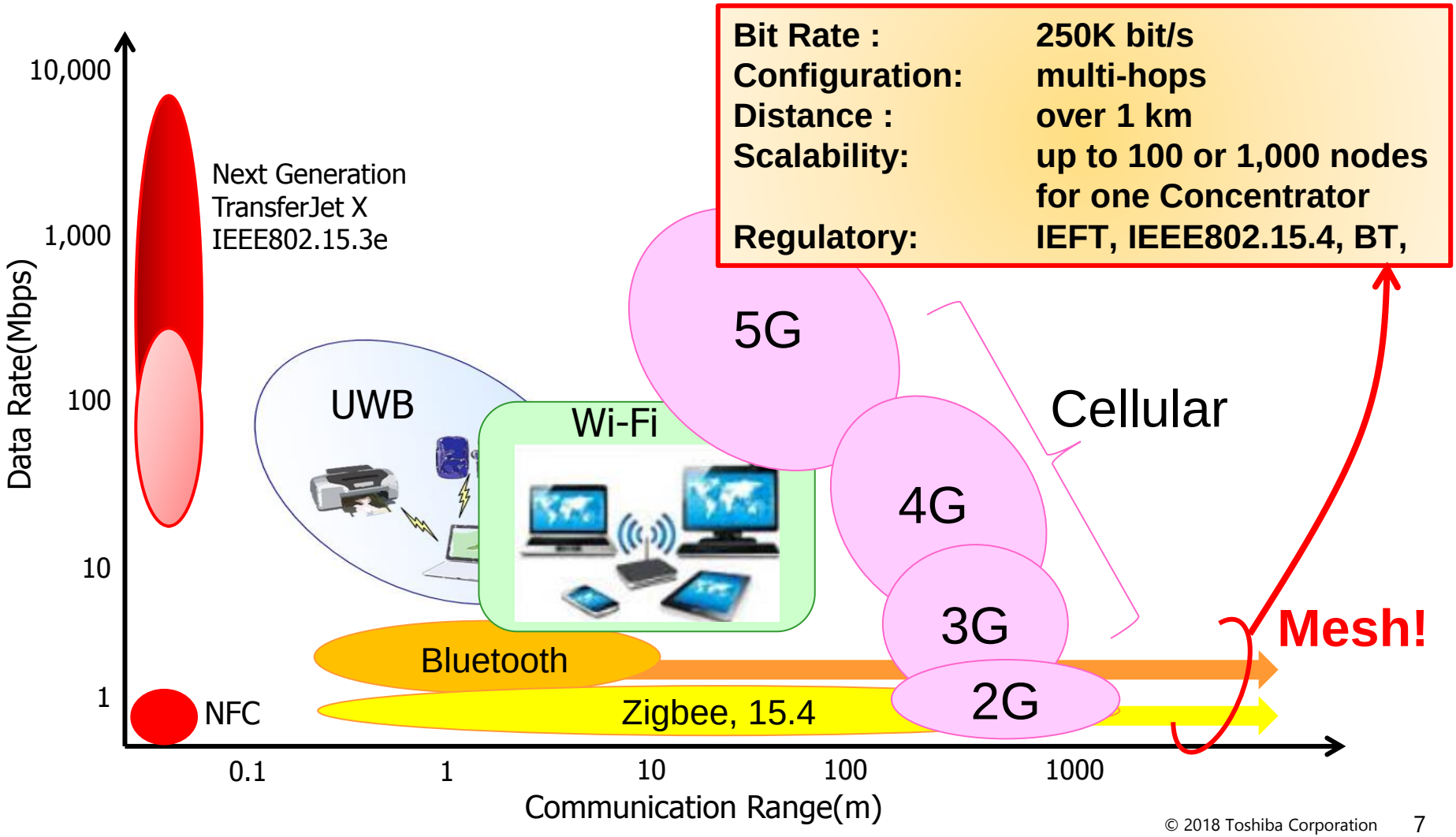
Wireless Portfolio regarding Mesh Network

Mesh Network extend distance due to collaborating with each other



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Dependable Industrial Wireless

From monitoring to control

Industrial Monitoring

•Monitoring of plant and remote assets for proactive maintenance

Remote Operation

•Construction sites, mining, harbors, etc.
•Hazardous environments e.g., nuclear reactors,
•Remote driving

2017 2019 2021 2023

IoT: Massive Sensing

Ubiquitous: Steering & Control

Tactile: sensing & Control

Industrial Control

•Process automation: Hydroelectric plants
•Factory automation: Assembly lines

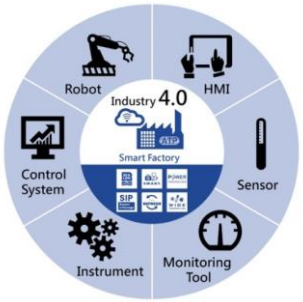
Haptics/ Tactile Internet

•Tele-surgery
•Tele-diagnostics

Industry 4.0

Connected and AI

- ✓ Wired connected
- ✓ Uniformed analysis
- ✓ Centralized



Beyond Industry 4.0

Wireless, Virtual, Distributed, Mobile in Robotics Autonomous System Networks

- ❑ Massive wireless network
- ❑ Specialized/customized automatically
- ❑ Distributed/Self-organized

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03

Large-scaled mesh network

ETSI - 6TiSCH Interoperability Event – 2017, 2018

ETSI World Class Standards

Certificate of Participation

awarded to

Toshiba Research Europe Ltd

for their attendance at the Plugtests event for

1st F-Interop 6TiSCH Interoperability Event

Prague, 14th to 15th July 2017

15th July 2017

The issuance of the present document does not imply any form of certification by ETSI

Jürgen Früs
ETSI Chief Service Officer

ETSI - 650, route des Lucioles - 06921 Sophia Antipolis Cedex - France
www.etsi.org

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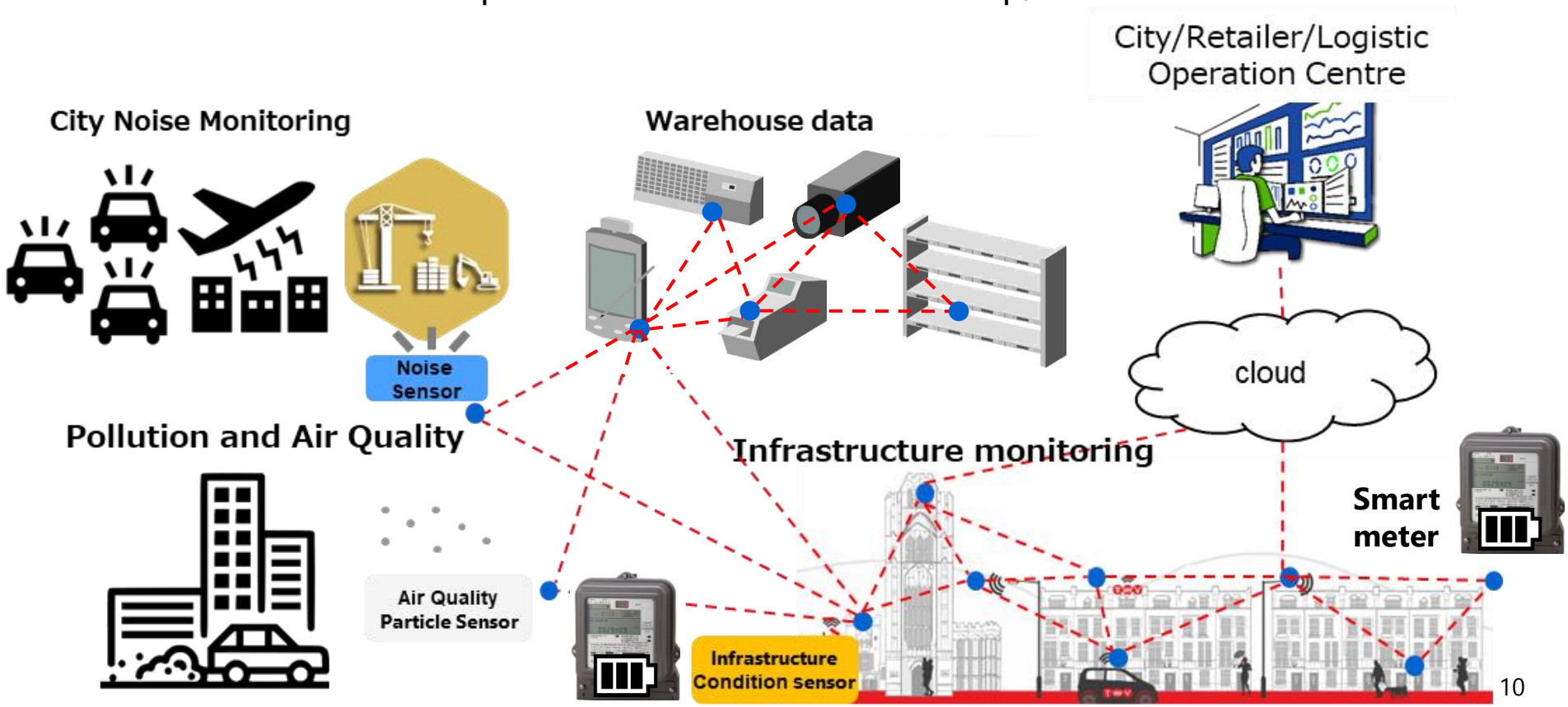
Massive Monitoring Applications

Large-scaled network with over 1,000 nodes

Data collection over 10 km range area and recognition function in a centre

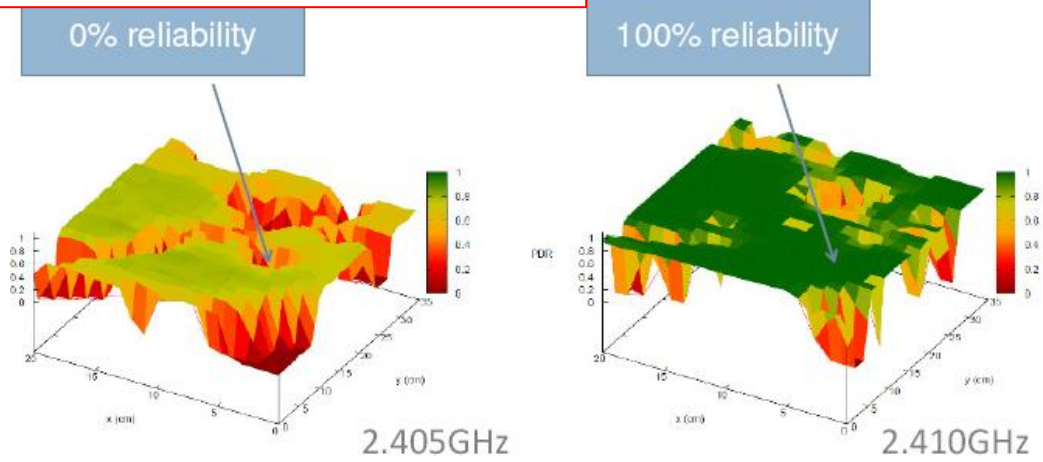
- Smart meter / Smart city sensing
- Infrastructure monitoring
- Data collection and predictive maintenance at shop/warehouse



Technology challenges in Mesh Network

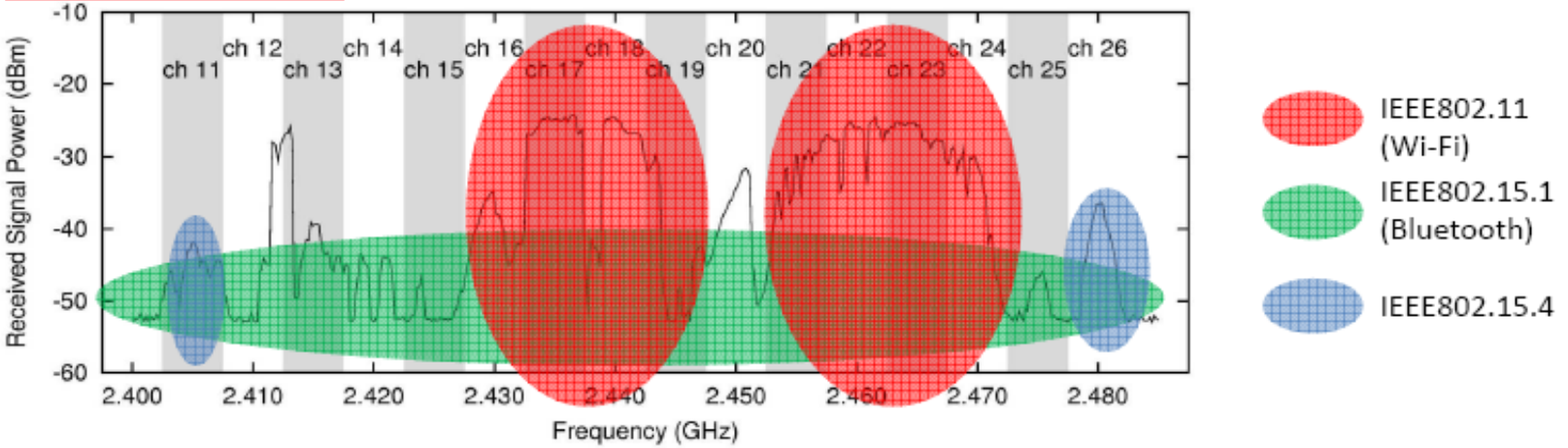
Scheduling considering Radio propagation performance, battery life, relay times …

Multipath Fading

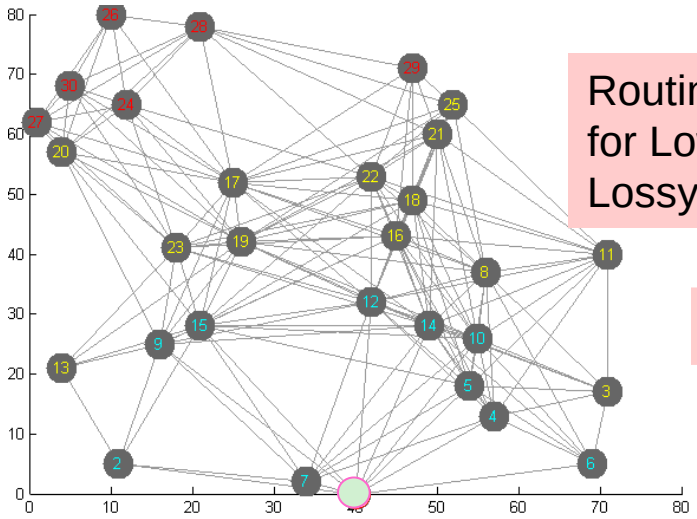


Need to avoid them

Interference



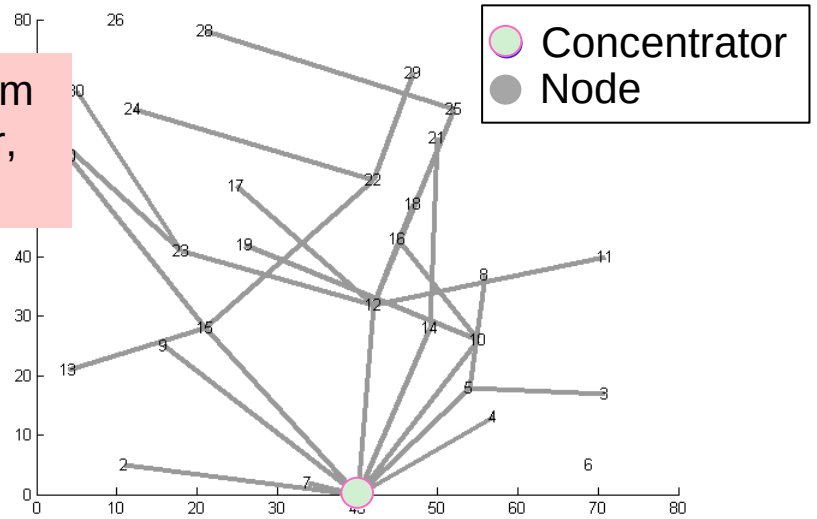
Scheduling steps to realize mesh network



Network topology graph G(V,A)

Routing Algorithm for Lower Power, Lossy Networks

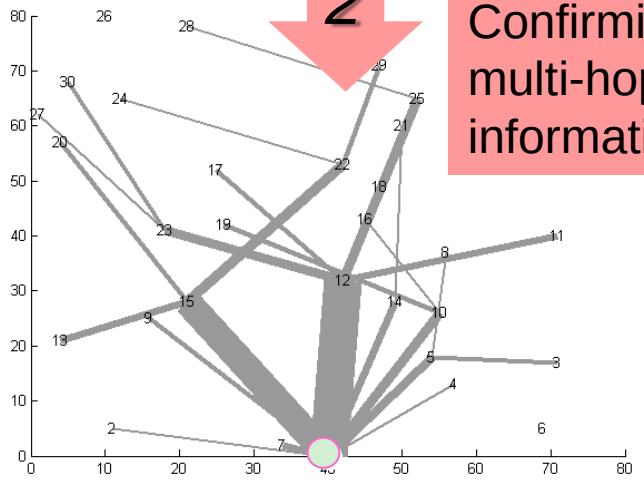
1



Tree topology graph T(V,E)

2

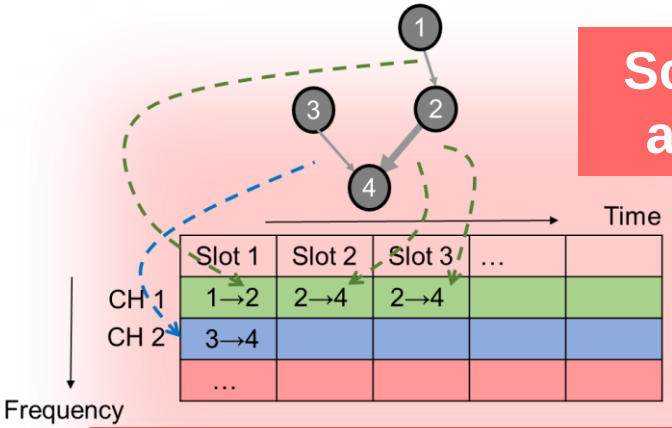
Confirming multi-hop traffic information



Traffic topology graph Gt(V,ℓ(e))

Scheduling algorithm

3



Resource Allocation Optimization in Time slot and Channel offset,
"TSCH ; Time Synchronized Channel Hopping"

Refer to IEEE802.15.4, 4e, IETF 6TiSCH

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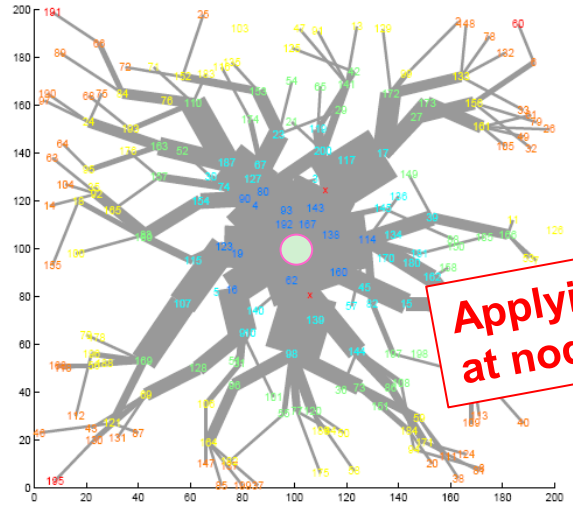
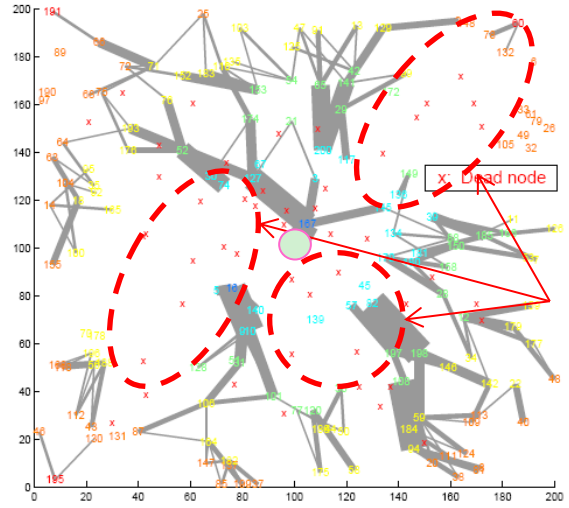
Large-scaled mesh performance for longer life

Standardized scheduling



(c) Central @ 50 rounds

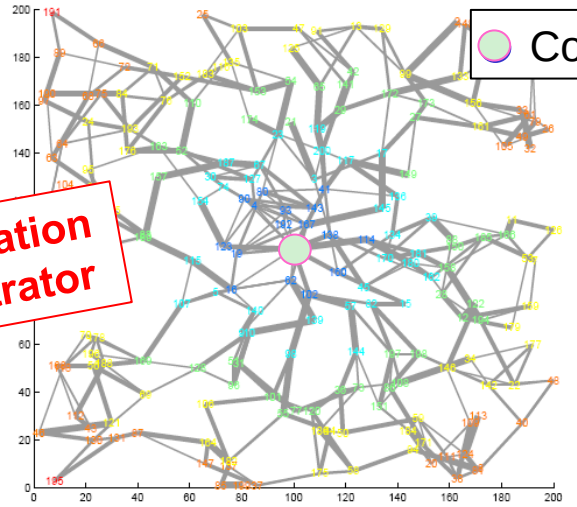


(f) Central @ 300 rounds

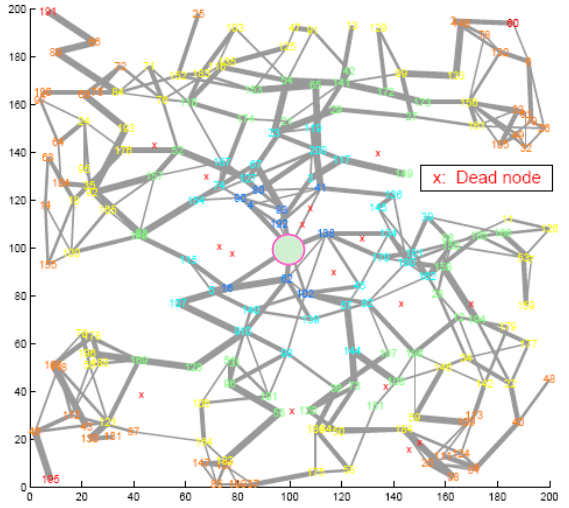
Applying data aggregation at node near Concentrator

Network Partitions happen

Concentrator



(a) CLADA @ 50 rounds



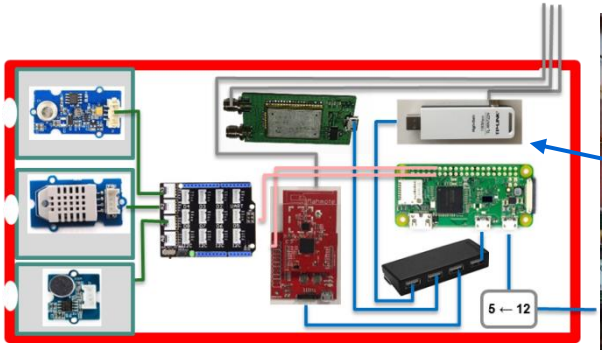
(d) CLADA @ 650 rounds

Our scheduling

battery life of nodes can be doubles along communication round

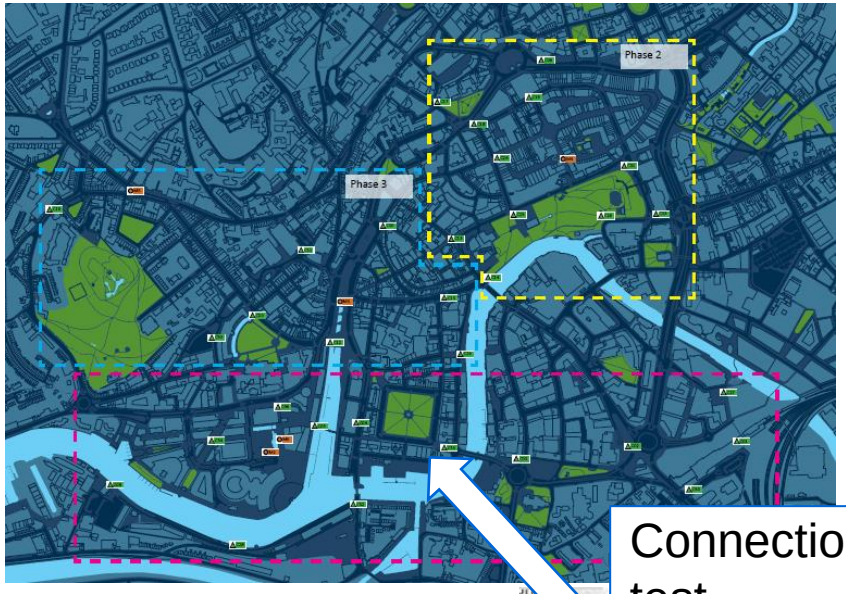
Field Trial Test with Bristol City Council

Mesh performance in the filed, Applying multi radio for reliability improvement



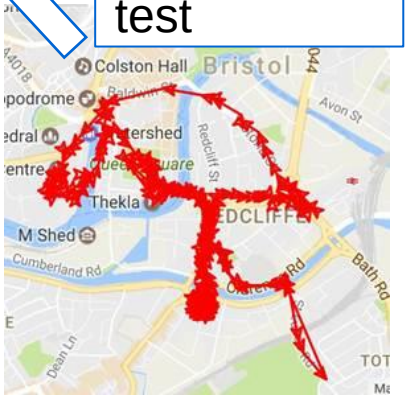
An array of sensors such as light, temperature, humidity, air quality, noise, spectrum usage etc.
&
Short range for Mesh and long range radio communication interfaces

Wayfinder Board in Bristol City



Location of Wayfinder Boards in Bristol city

Connection test



32 nodes covering major part of the city centre of Bristol,

Planning to evaluate mesh against long range radio,

04

Ultra low latency mesh network

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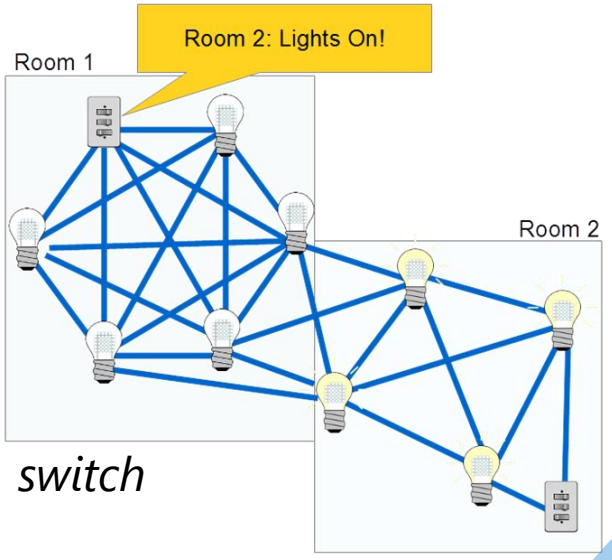
Wireless Control Applications

Ultra low latency / high reliable connections



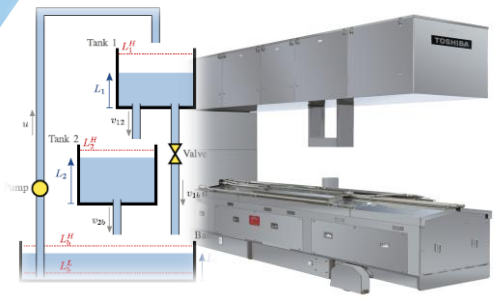
switch

Remote Operation Haptics

1-2 ms
99.99999%

Closed-Loop Control

5-10 ms
99.999%



Open-loop Control

50 ms
99.9%

alarms & control signals dissemination

Mobile control

Factory automation

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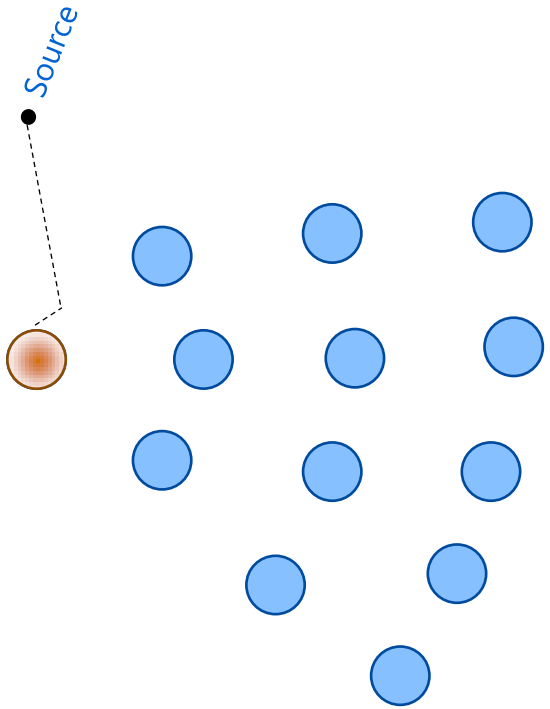
Providing low-latency connections for all nodes,

Concurrent Transmissions protocol, 'Flooding'

Design target; designing MAC layer with Bluetooth PHY layer reliability of 99.999% or more with over 100 nodes



Merit

- No need for complex routing protocols
- No complex scheduling
- Can support unpredictable traffic volumes

Concern

✓ Trade-offs among latency, reliability and energy efficiency

✓ Sensitive to high-density nodes

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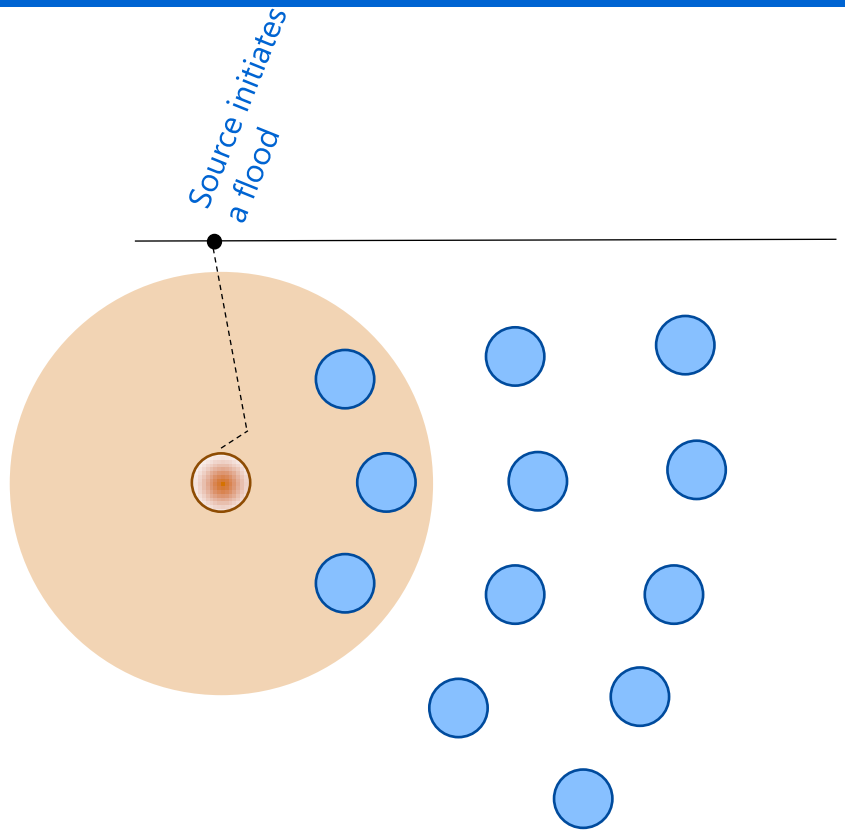
Concurrent Transmissions based Flooding

Source initiates a flooding to send a packet



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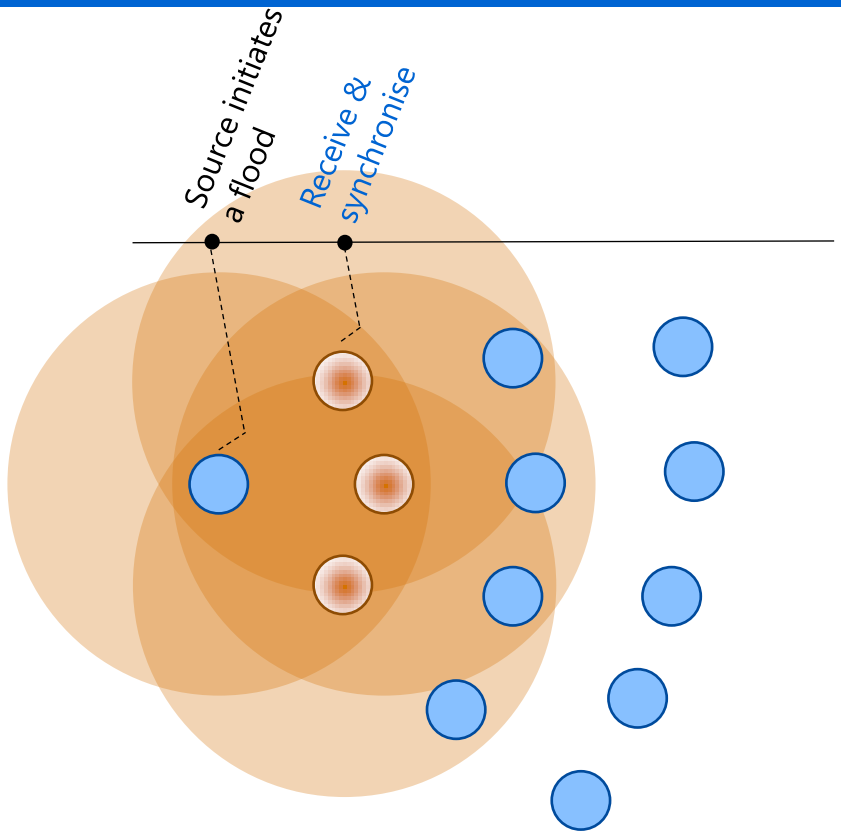
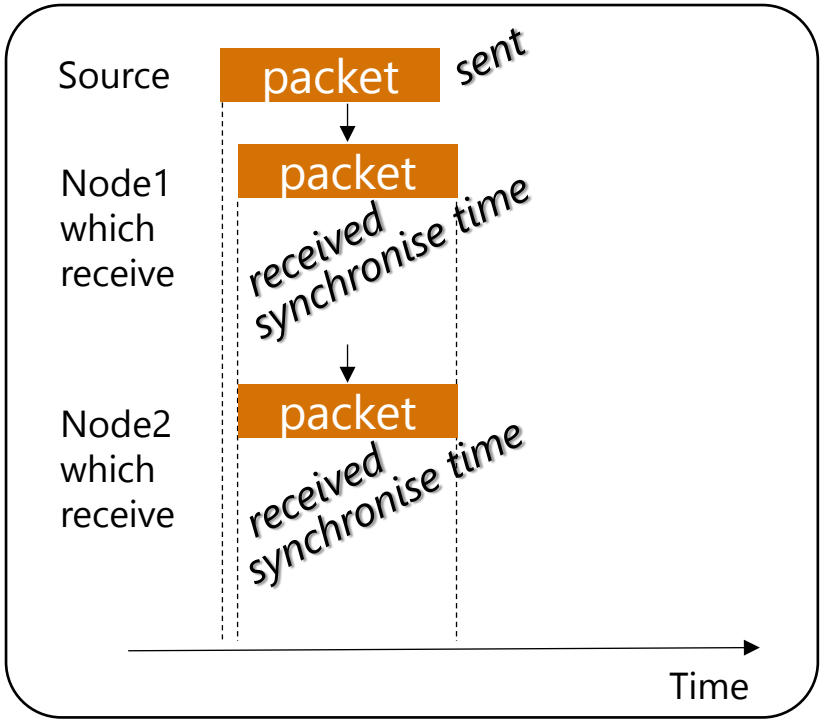
Concurrent Transmissions based Flooding

Nodes receive and synchronise to send a packet





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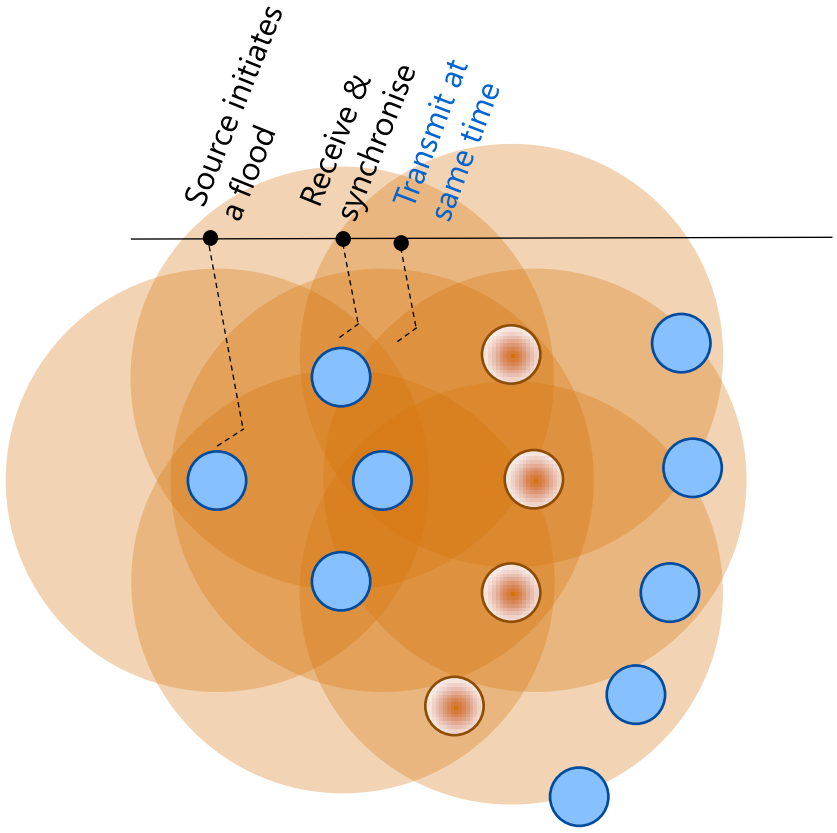
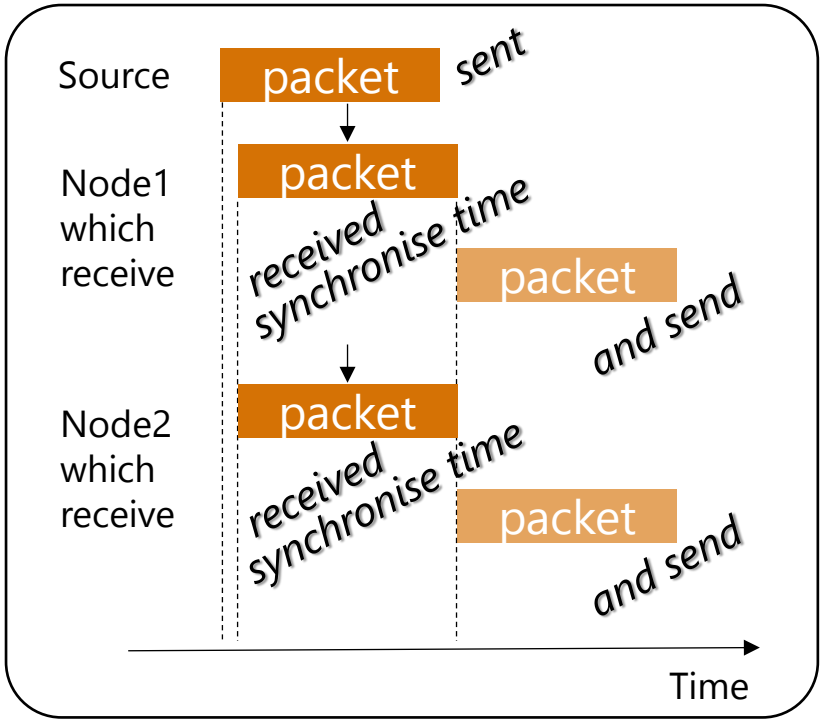
Concurrent Transmissions based Flooding

Send a packet at the same time at each node which received the packet





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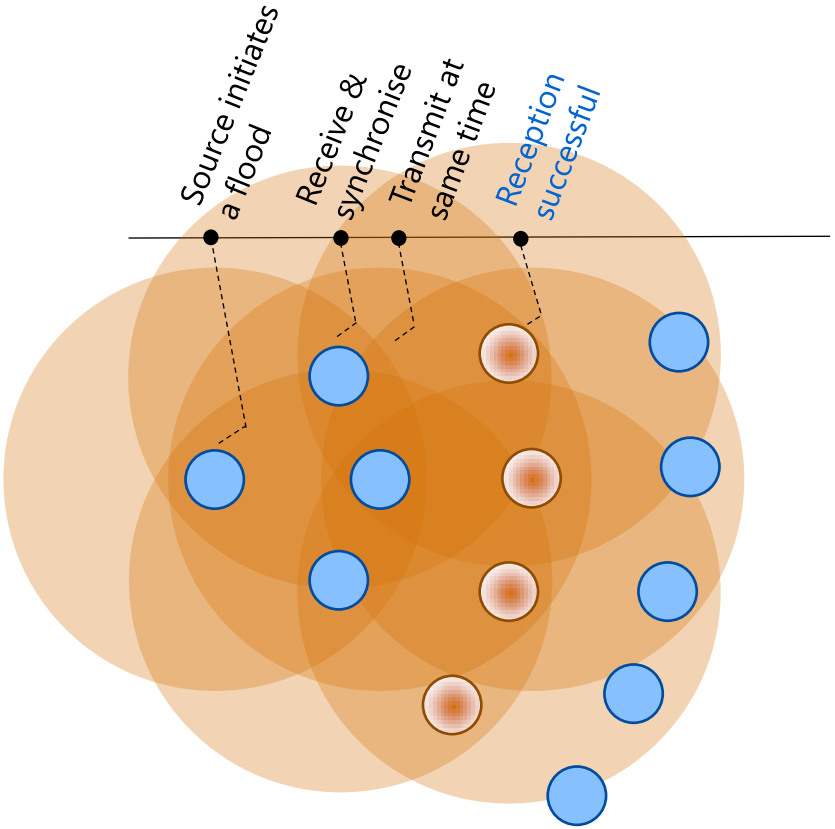
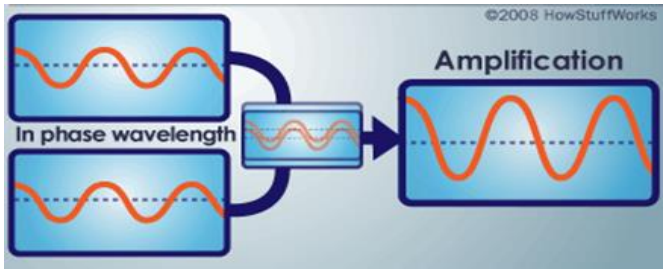
Concurrent Transmissions based Flooding

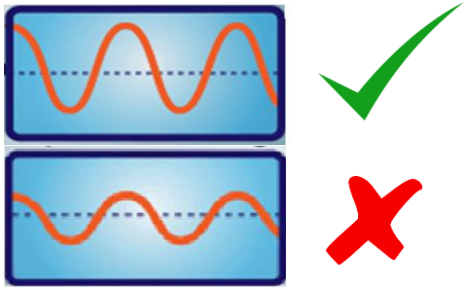
Nodes receive packets sent at the same time



Although multi-path fading and co-channel interference happens in RF domain,



Constructive Interference in data domain



Capture Effect due to demodulation scheme

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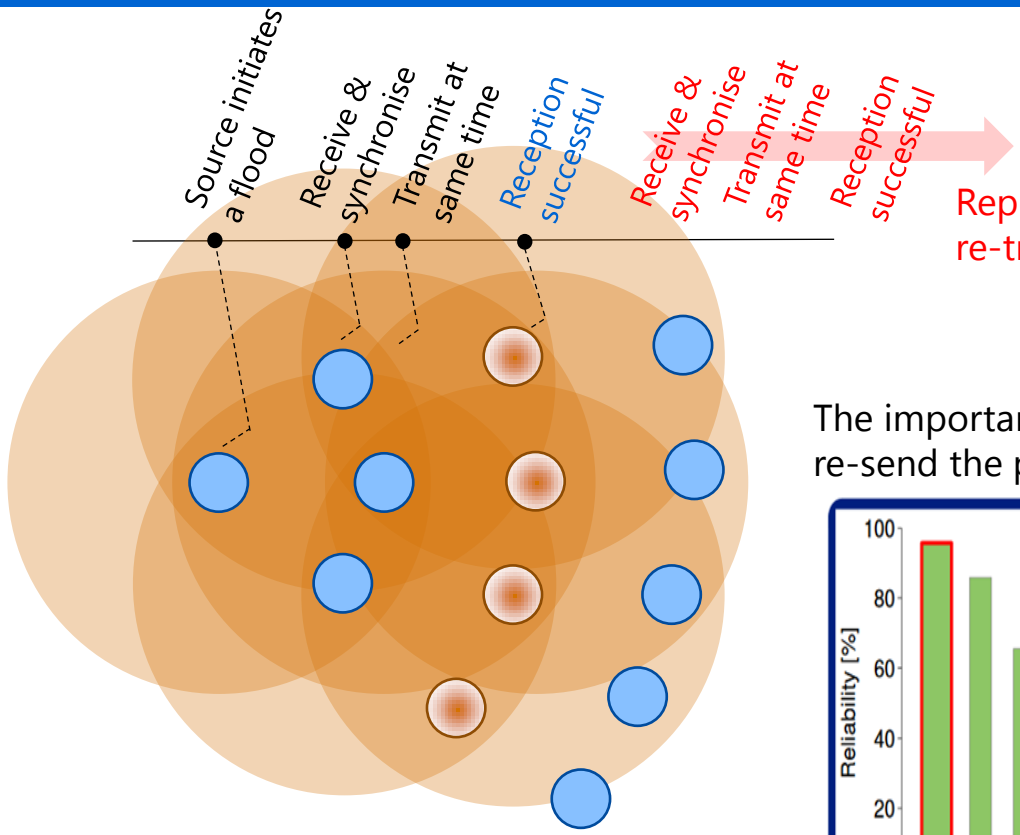
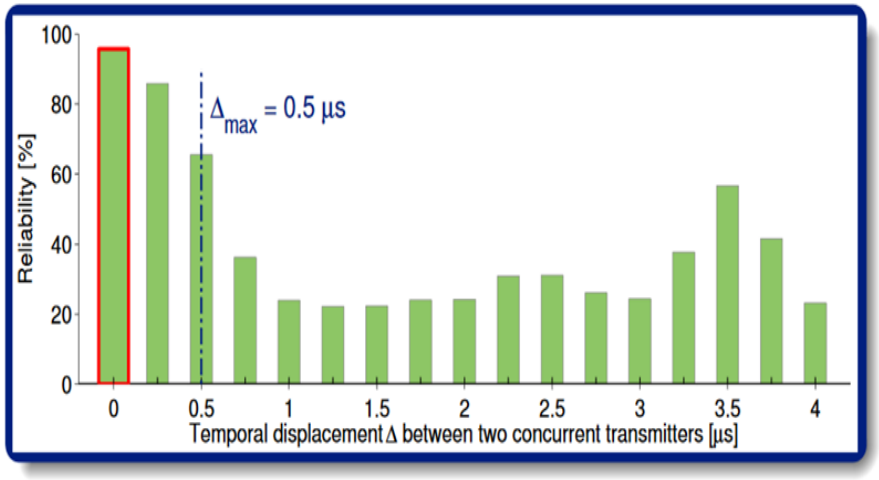
Concurrent Transmissions based Flooding

Nodes receive packets sent at the same time



Repeat this flow up to pre-set re-transmission times,

The important factor is how quick each node can re-send the packet, which leads reliability performance



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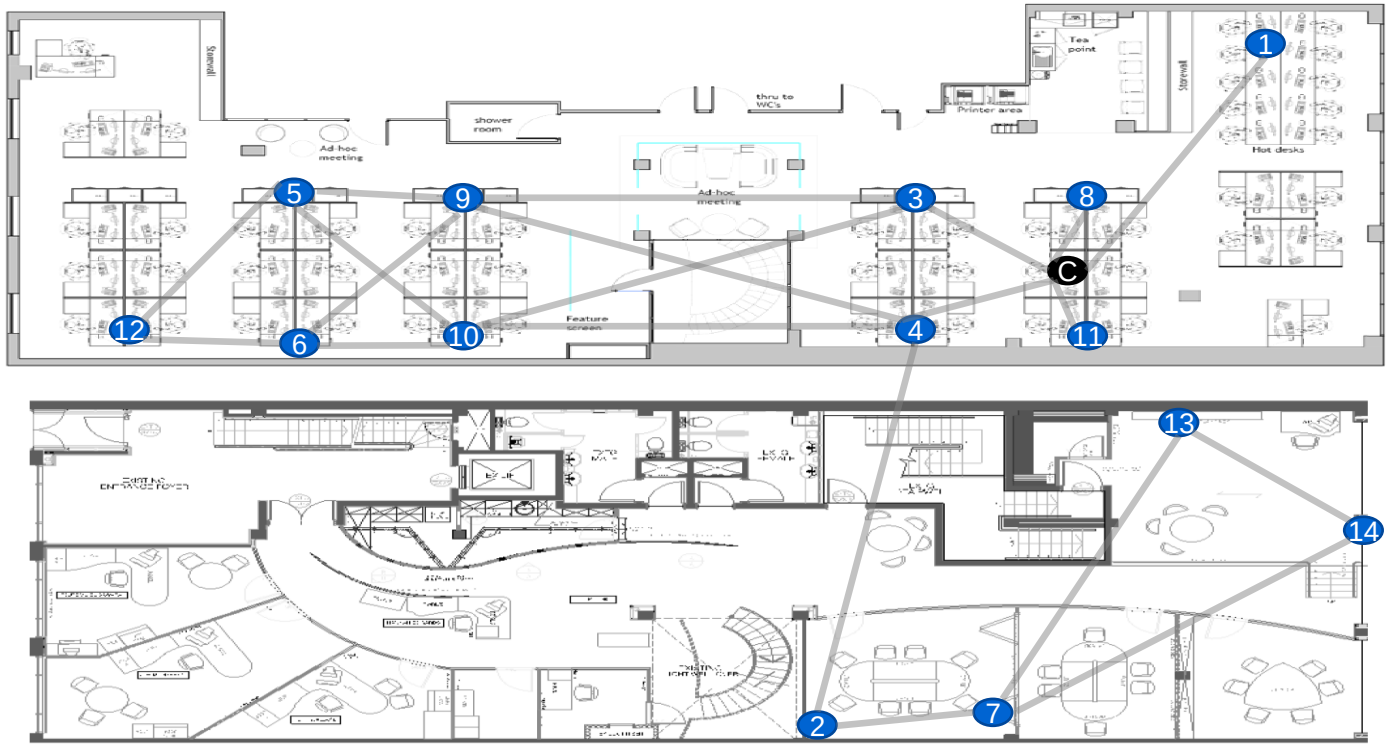
Evaluation of flooding solution

Experimental setup

Performance Metrics

- Reliability : % of packets against which the client received the reply from the nodes
- Latency : The duration between the client Tx-packet front-edge and the received packet back-edge of nodes



HW: nRF52840 Preview DK
SW: nRF5 SDK for Mesh v0.10.0-alpha

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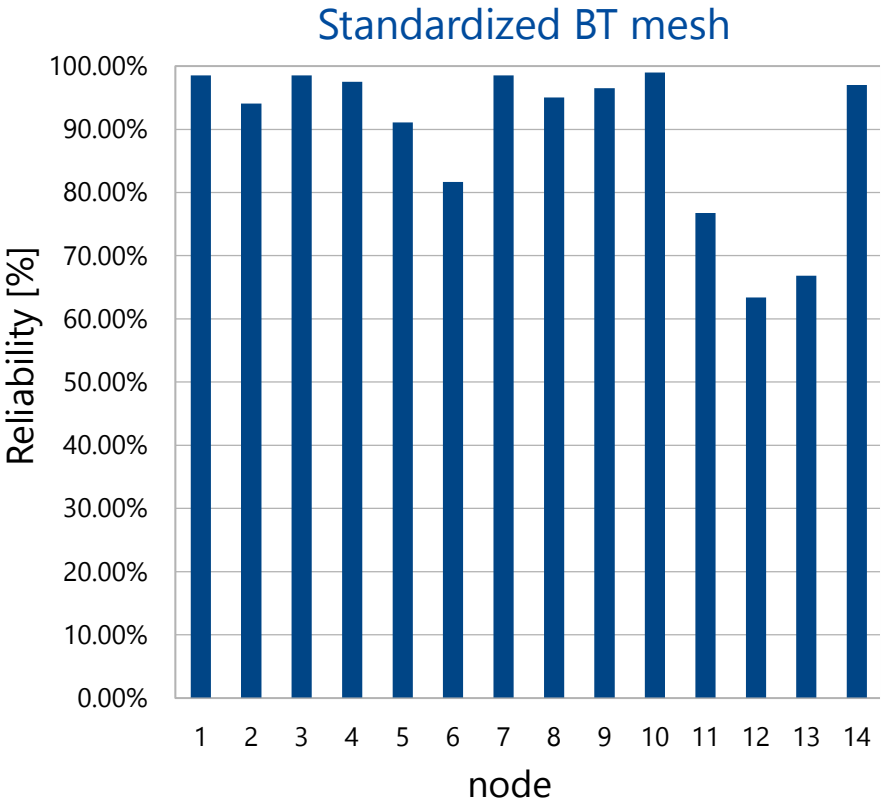
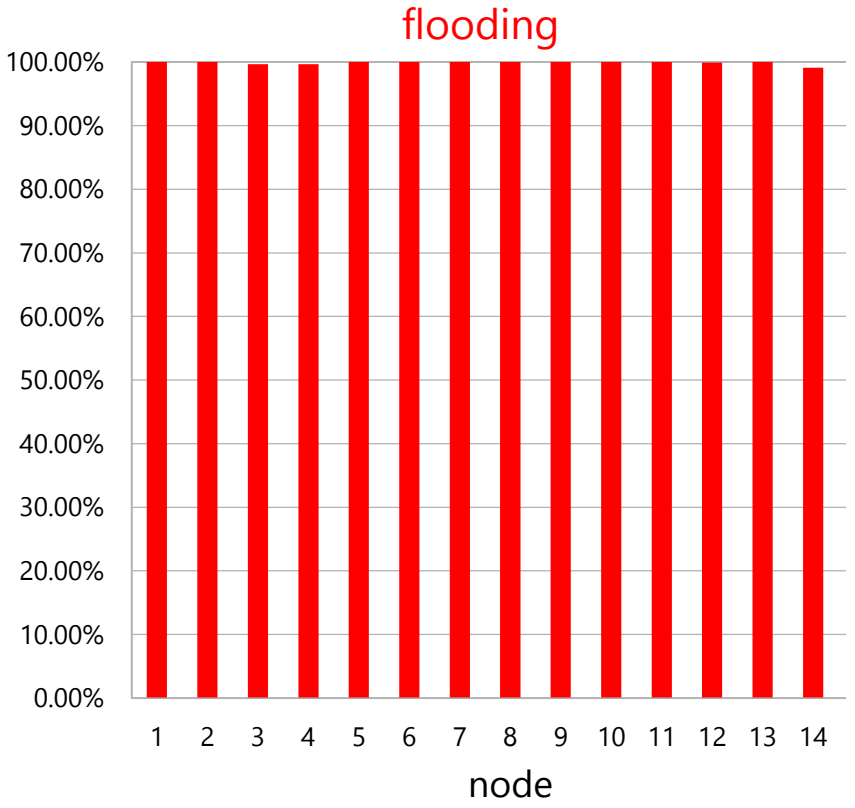
Comparison in reliability against standardized BT

Conditions; Packet length= 13 bytes (10B payload + 3B header)
4 re-transmission attempts





Reliability : % of packets against which the client received the reply from the nodes

Higher reliability has been achieved

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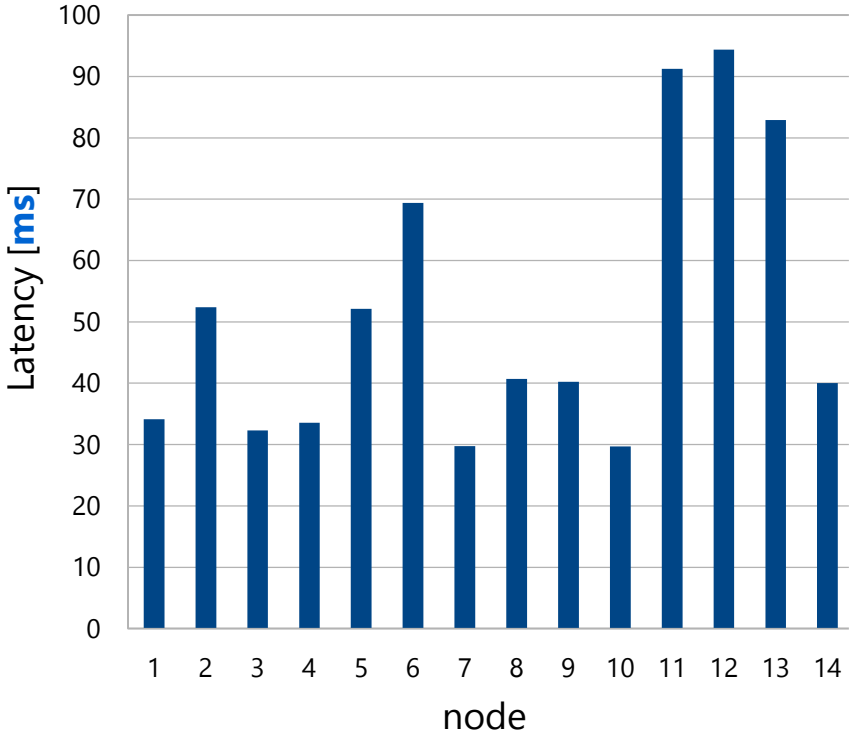
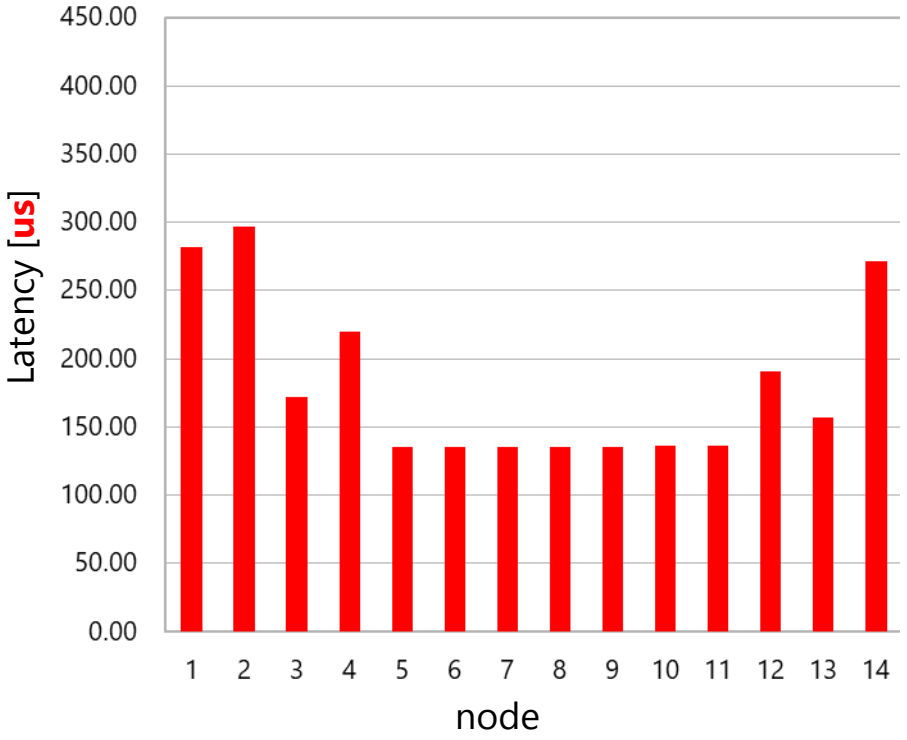
Comparison in latency against standardized BT

Conditions; Packet length= 13 bytes (10B payload + 3B header)
4 re-transmission attempts

Standardized BT mesh



flooding



Latency : The duration between the client Tx-packet front-edge and the received packet back-edge of nodes

2 orders of magnitude better in latency

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Comparison against standardized BT

	BT mesh	Our designed flooding	Our designed another one
Protocol	Bluetooth PHY + Bluetooth LL +Mesh Stack	Bluetooth 4.0/5.0 PHY/HW + Proprietary stack (fully bottom-up design)	
Latency	250-400 msec	5-30 msec depending on packet size	< 10 msec # for closed-loop control
Reliability	99 %	> 99.999 %	
Scalability	100 – 130 devices / 7 devices per master device	up to 100 -130 devices / large number of devices per master device	
Interference resilience	Can use only 3 advertising channels at maximum speed of 1Mbps	Can exploit all (40 BLE/80 BT) channels at maximum speed of 2Mbps (Bluetooth 5.0)	

available to apply for open-loop toward closed-loop control

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Summary

Mesh network has high potential beyond cellular

- Mesh network is expected in industrial IoT applications
  - ✓ Covering wide area to be connect to cloud
  - ✓ Massive Monitoring
  - ✓ Control with open-loop
  - ✓ Control with closed loop
  - ✓ Reducing operational costs

- Next technology topics toward beyond industry 4.0
  - ✓ Latency
  - ✓ Reliability
  - ✓ Scalability

❖ Aiming to replace wired connections with wireless connections,

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Thank you

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