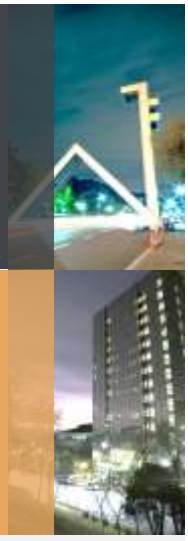

Seoul National University

Title: IoT

Date

Name: Chong-kwon Kim

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Internet of Things

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- The Internet of Things, or IoT, is a network of physical devices that are connected to the Internet and are able to "talk" to each other
- There are many wireless technologies you can use to connect these devices to the Internet
  - Short-range wireless communication
  - Cellular communication
  - LPWAN communication

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LPWAN

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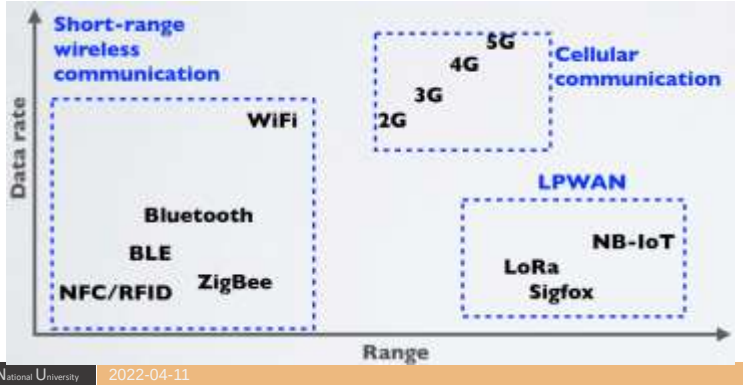
- LPWAN stands for Low Power Wide Area Network and this type of wireless communication is designed for sending small data packages over long distances, operating on a battery.
- There are a number of competing technologies in the LPWAN space such as: Narrowband IoT (NB-IoT), Sigfox, **LoRa** and others



Network Technologies

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Wireless Technology	Wireless Communication	Range (m)	Tx power (mW)
Bluetooth	Short range	~10	~2.5
WIFI	Short range	~50	~80
3G / 4G	Cellular	~5000	~500
LoRa*	LPWAN	2000-5000 (urban area) 5000-15000 (rural area) > 15000 (direct line of sight)	~20

LPWAN Use Cases

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- Smart utilities
  - Power transformer monitoring
  - Water level monitoring
  - Utility meter, AMI (Advanced Metering Infra.)
  - Fuel monitoring (monitoring fuel levels in fuel tanks for heating houses)
- Health & Hygiene
  - Temperature / humidity monitoring
  - Environmental monitoring
  - Waste management (monitoring waste level in waste bins)

LoRa Devices

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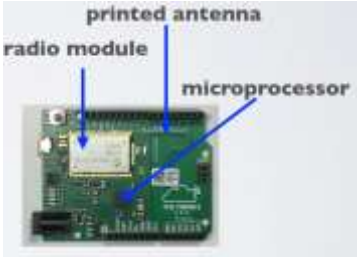
- LoRa is an acronym for Long Range and it is a wireless technology where a low powered sender transmit small data packages (0.3 kbps to 5.5 kbps) to a receiver over a long distance
- A gateway can handle hundreds of devices at the same time
- LoRa end node



LoRaWAN Topology

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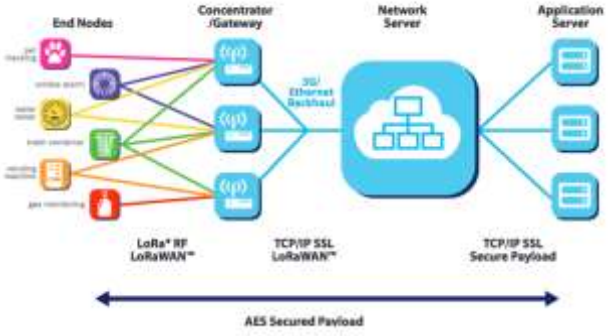
- LoRaWAN is deployed in a star topology
- The communication between the end node and gateway is bidirectional which means the end node can send data to the gateway but it can also receive data from the gateway.



ISM Band

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- LoRa operates in the unlicensed ISM (Industrial, Scientific and Medical) radio band that are available worldwide
- Devices such as microwave ovens, medical equipments or baby monitors all uses the ISM band

- ISM band advantages
  - Anyone is allowed to use these frequencies
  - No license fee is required
- ISM band disadvantages
  - Low data rate
  - Lots of interference because anyone can use these frequencies.

LoRa Device Types

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Type	
A	Battery powered devices. Each device uplink to the gateway and is followed by two short downlink receive windows.
B	Same as class A but these devices also opens extra receive windows at scheduled times.
C	Same as A but these devices are continuously listening. Hence these devices uses more power and are often mains powered.

LoRa Communications

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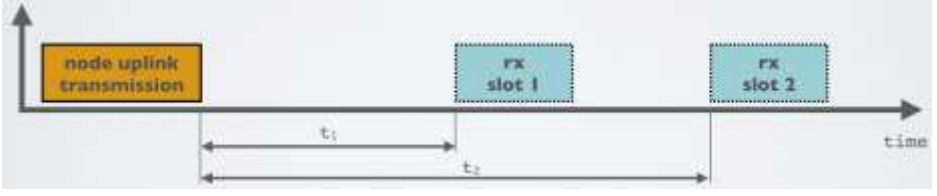
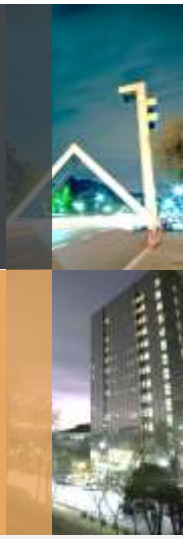
- At any time an end node can broadcast a signal
- After the uplink transmission (tx) the end node will listen for a response from the gateway
- The end node opens two receive slots at t1 and t2 seconds after an uplink transmission
- The gateway can respond within the first receive slot or the second receive slot, but not both





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Introduction

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- The demand to monitor or control devices scattered to the space in an ad-hoc manner

- Examples
  - Disaster monitoring & recover
    - Fire detection (Home, market, mountain,…) flooding,
    - Search & rescue
  - Home/Building automation
  - Industry 4.0
  - Smart grid (AMI: Advanced Metering Infra)
  - Healthcare
  - …

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LLN

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- Low power Lossy Network
  - IoT devices may have limited resources
    - Battery-operated
    - Limited CPU power and small memory
  - Lossy network
    - Low power network technologies such as ZigBee(IEEE 15.4) or Bluetooth
    - ISM band prone to interference from WiFi, MW, page, etc
    - Ad hoc network operation and management
- Requirements
  - Low traffic
  - Reliability
- Other alternatives
  - Cellular (5G)

RPL

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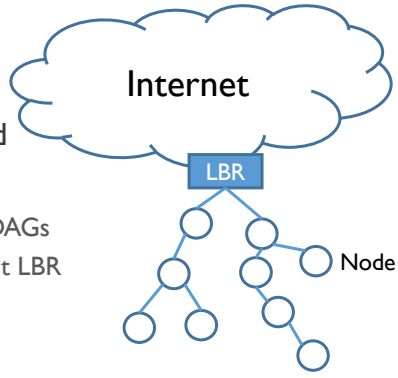
- Routing Protocol for LLN
- Simple but as efficient as possible
- Based on DAG (Directed Acyclic Graph) rooted at LBR(LLN Border Router)
  - LBR provides the access to the Internet
- DODAGs(Destination Oriented DAG)
  - A network may have several DODAGs each of which is rooted at different LBR



Configuration of DODAG

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- LBR initiates the construction of its own DODAG
  - Unique DODAG ID
  - Similar to ND(Neighbor Discovery) of IPv6
  - Similar to DV (Distance Vector)
- Control messages for RPL
  - Based on ICMPv6 message
  - DIO (DODAG Information Object)
  - DIS (D. Information Solicitation)
  - DAO (D. Advertisement Object)
- Aims to build an efficient tree rooted at the LBR
  - Efficiency: shortest path
  - Metrics
    - Hop, ETX, Energy, …

Configuration of DODAG

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- RPL uses rank and OF to construct loop free tree
  - Principle: The rank increases strictly as the location of a node deepens
  - When a node selects its parent, consider only candidates whose ranks are smaller than itself
- LBR initiates the flooding of DIO
  - Rank = 1 (same as distance in DV)
  - OF(Objective Function)
    - Defines how nodes calculate rank
  - Nodes that hear the DIO select the LBR as their parent
    - May use a constraint that ETX should be less than 2
- RPL allows the freedom to use define metrics for rank computation and OFs

Configuration of DODAG

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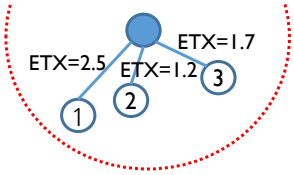
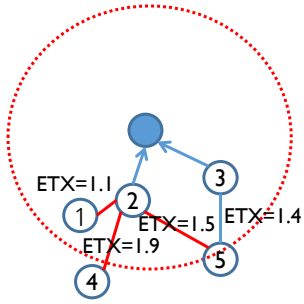
- Suppose that
  - Use hop as the rank and ETX for parent selection
    - Used in TinyOS
    - ETX should be less than 2.0



Nodes 2 and 3 select LBR as their parent
  Update rank = 2
Node 3 does not select the LBR



Nodes 1 and 4 select node 2 as their parent
  Update rank = 3
Node 3 also receives node 2's DIO
  Ignore because its rank(2) is not less than rank(3)
Node 5 receives DIO from node 2 and 3
  Select 3 because ETX(3,5) < ETX(2, 5) ➔ Some inefficiency

Configuration of DODAG

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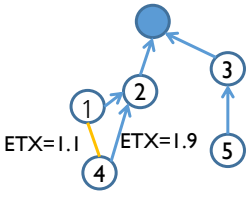
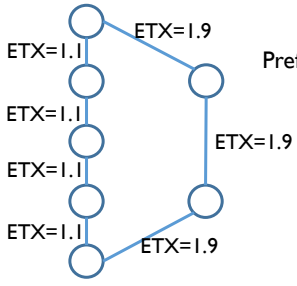


Nodes 4 receives DIO from node 1
  Ignore because rank(1) = rank(4)

- Some problems



Preference of short hop paths

Routing

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- RPL supports
  - MP2P, P2MP and P2P
- At least each node knows its parent
- Two modes of node
  - Storing node: Know children
  - Non-storing node
- Routing information creation
  - Nodes generates DAO message periodically toward the root
    - A storing node unicast DAO to the selected parent
      - In DAO, IDs of node itself and its children are written
    - A non-storing node unicast DAO to the DODAG root
  - Upon receiving a DAO from its children,
    - A storing parent records the IDs of the children
    - A non-storing parent write its ID on the DAO and forwards the DAO upward to the root

Routing

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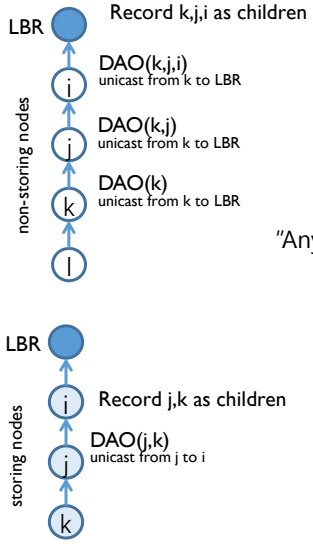

MP2P: Nodes to LBR
Moves to parent

P2MP: LBR to nodes
Source routing via storing nodes
Source routing to k and then source routing to m

"Any two pancakes taste similar."

P2P: Node to node
Move upward until the first common storing parent
Then move downward

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