

Ôn tập NT532 - Công nghệ Internet of Things hiện đại

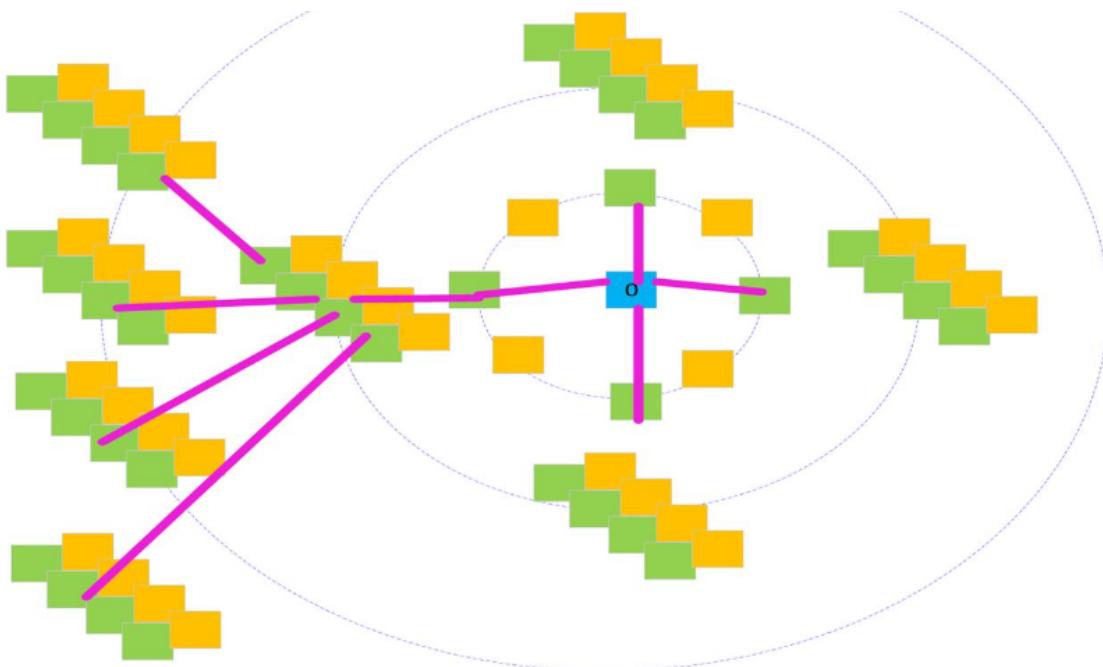
ZigBee - 802.15.4

Theory

Note: You can find more documents in Lecture 2

- Maximum number of routers: R_m
- End devices that each router may have children: D_m
- Maximum depth of tree: L_m
- Size of the address range: $A(d)$
 - $A(d) = 1 + D_m + R_m$, if $d = L_m - 1$
 - $A(d) = 1 + D_m + R_m \times A(d + 1)$, if $0 \leq d < L_m - 1$
- Router at depth d 's address range: $R(x) = [x, x + A(d)]$
- i-th child router's ($1 \leq i \leq R_m$) address range:
 - $[x + (i - 1) \times A(d + 1) + 1, x + i \times A(d + 1)]$
- j-th child end-device's ($1 \leq j \leq D_m$) address:
 - $x + R_m \times A(d + 1) + j$

**(Exercise): Assign address for all nodes, with
 $R_m = 4, D_m = 4, L_m = 3$**

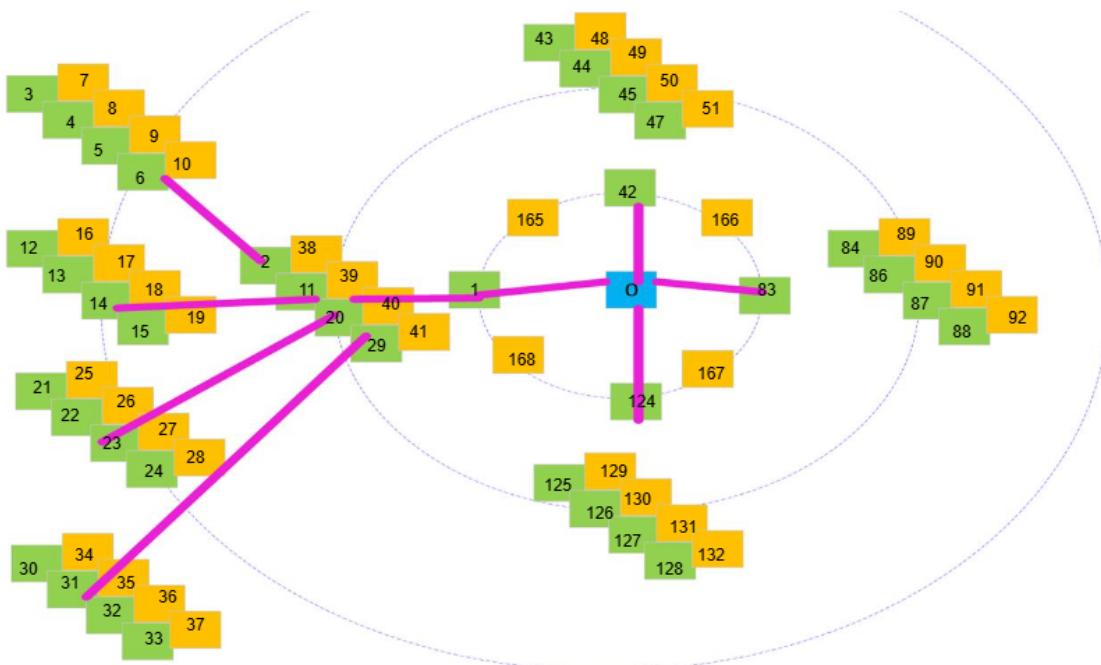


⋮ $R_m=4$, $D_m=4$, $L_m=3$

Nót BLUE: Coordinator/FFD, Nót GREEN: Router/FFD, Nót ORANGE: End Device/RFD

- This topology has three depth levels: 0, 1, 2
- Size of address range for each depth level:
 - $A(2) = 1 + 4 + 4 = 9$
 - $A(1) = 1 + 4 + 4 \times A(2) = 41$
 - $A(0) = 1 + 4 + 4 \times A(1) = 169$
- Address range at coordinator: $R(0) = [0, 0 + A[0]] = [0, 169]$
 - 1st child router: $[0 + (1 - 1) \times A(1) + 1, 0 + 1 \times A(1)] = [1, 41]$
 - 2nd child router: $[0 + (2 - 1) \times A(1) + 1, 0 + 2 \times A(1)] = [42, 82]$
 - 3th child router: $[0 + (3 - 1) \times A(1) + 1, 0 + 3 \times A(1)] = [83, 123]$
 - 4th child router: $[0 + (4 - 1) \times A(1) + 1, 0 + 4 \times A(1)] = [124, 164]$
 - 1st child end-device: $0 + 4 \times A(1) + 1 = 165$
 - 2nd child end-device: $0 + 4 \times A(1) + 2 = 166$
 - 3th child end-device: $0 + 4 \times A(1) + 3 = 167$
 - 4th child end-device: $0 + 4 \times A(1) + 3 = 168$
- Address range at router: $R(1) = [1, 41]$
 - 1st child router: $[2, 10]$
 - 2nd child router: $[11, 19]$
 - 3th child router: $[20, 28]$
 - 4th child router: $[29, 37]$
 - 1st child end-device: 38
 - 2nd child end-device: 39

- 3th child end-device: 40
- 4th child end-device: 41
- *Repeat the process until all devices have been assigned*



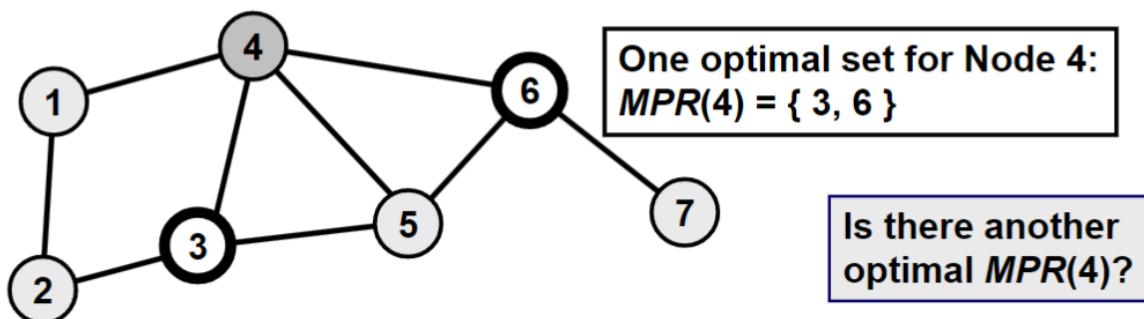
⋮ $R_m=4$, $D_m=4$, $L_m=3$
 Note: BLUE: Coordinator/FFD, GREEN: Router/FFD, ORANGE: End Device/RFD

Optimized Link State Routing protocol - OLSR

Theory

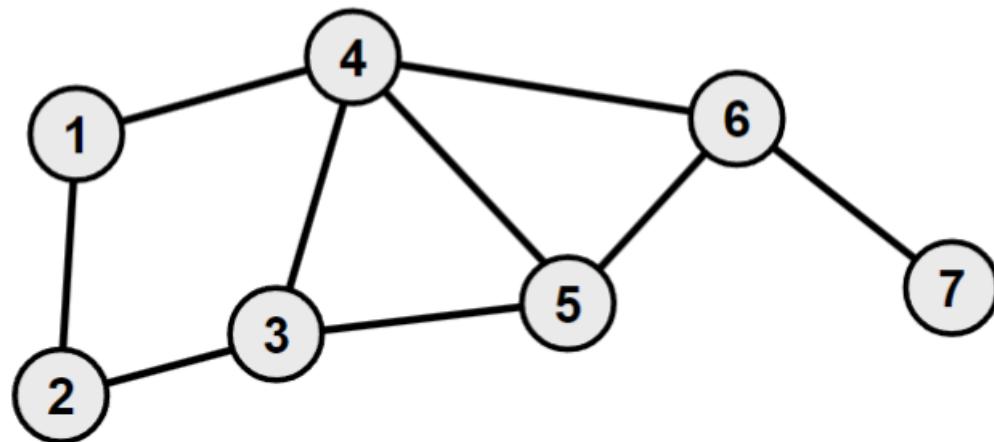
Note: You can find more documents in Lecture 5

- Multipoint relay set - MPR(N): a set of 1-hop neighbor nodes that can transmit control packet from node N to 2-hop neighbor nodes
 - Example at node 4



- Multipoint relay selector set - MS(N): a set of SOURCE NODES (in 1-hop neighbor) selected N to forward THEIR broadcasted packets, to cover all 2-hop neighbor nodes

- Example at node 3



$$MPR(1) = \{ 4 \}$$

$$MPR(2) = \{ 3 \}$$

$$MPR(3) = \{ 4 \}$$

$$MPR(4) = \{ 3, 6 \}$$

$$MPR(5) = \{ 3, 4, 6 \}$$

$$MPR(6) = \{ 4 \}$$

$$MPR(7) = \{ 6 \}$$

$$MS(1) = \{ \}$$

$$MS(2) = \{ \}$$

$$MS(3) = \{ 2, 4, 5 \}$$

$$MS(4) = \{ 1, 3, 5, 6 \}$$

$$MS(5) = \{ \}$$

$$MS(6) = \{ 4, 5, 7 \}$$

$$MS(7) = \{ \}$$

- Neighbor list - NBR(N): a list of nodes that are indicated as node N's neighbors by sending and receiving HELLO message from node N, used to optimize MPR(N) NBR set.

- Example at node 4

At Node 4:

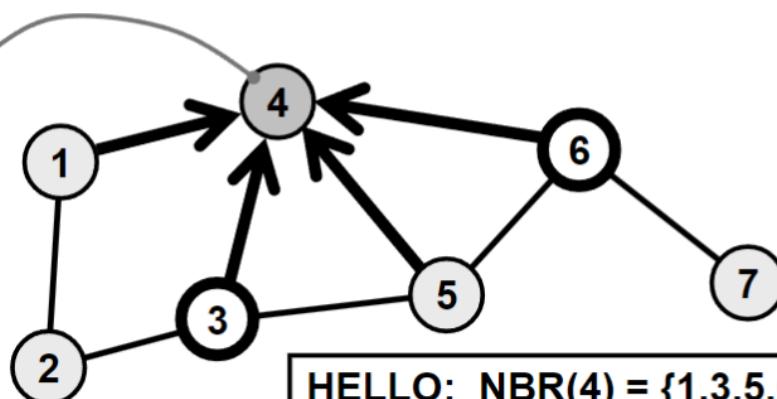
$$NBR(1) = \{ 2 \}$$

$$NBR(3) = \{ 2, 5 \}$$

$$NBR(5) = \{ 3, 6 \}$$

$$NBR(6) = \{ 5, 7 \}$$

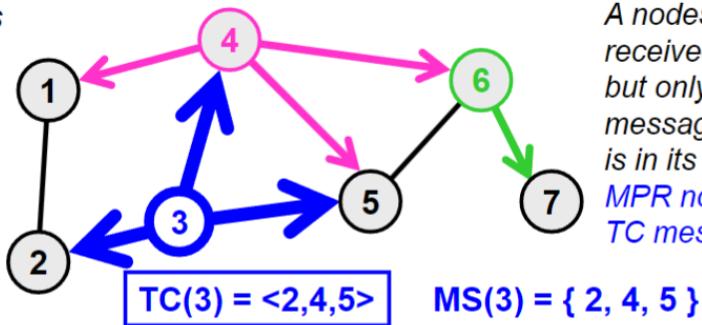
$$MPR(4) = \{ 3, 6 \}$$



- Topology Control message - TC(N): a list of advertised neighbors (link information) and sequence number (to prevent use of state information). Only MPR nodes generate and propagate TC message

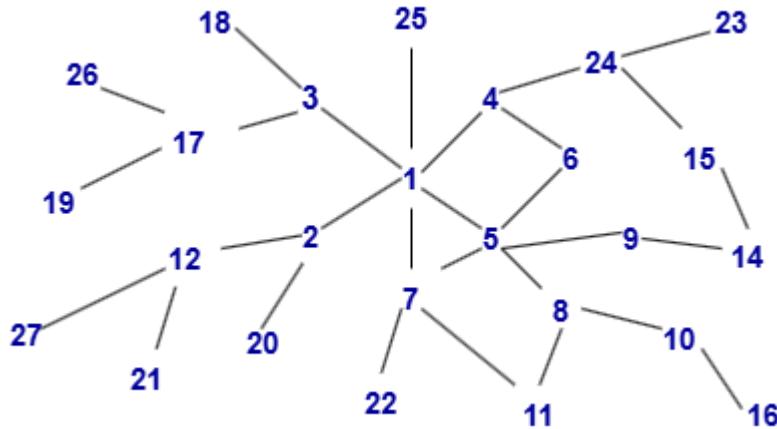
- Example at node 3

A node generates TC messages only for those neighbors in its MS set, i.e., only MPR nodes generate TC messages



A nodes processes all received TC messages, but only forwards TC messages if the sender is in its MS set, only MPR nodes propagate TC messages

(Exercise) Find: **MPR(1)**, **MPR(12)**, **MPR(5)**, **MPR(14)**, **MS(2)**, **MS(9)**, **MS(5)**, **MS(1)** following by this topology



- $MPR(1) = \{2, 3, 4, 5, 7\}$
- $MPR(12) = \{2\}$
- $MPR(5) = \{1, 6, 7, 8, 9\}$
- $MPR(14) = \{9, 15\}$
- $MS(2) = \{1, 12, 20\}$
- $MS(9) = \{5, 14\}$
- $MS(5) = \{1, 6, 7, 8, 9\}$
- $MS(1) = \{2, 3, 4, 5, 7, 25\}$

(Exercise) Given an IoT network including 6 nodes, draw the topology based on the nodes' routing tables and indicate the routing path from Node 6 to Node 1

Route Table of Node 1:

Destination	Next Hop	Hop Count
3	3	1
5	3	2
4	3	2
2	2	1
6	2	3

Route Table of Node 2:

Destination	Next Hop	Hop Count
1	1	1
5	4	2
4	4	1
3	4	2
6	4	2

Route Table of Node 3:

Destination	Next Hop	Hop Count
1	1	1
5	5	1
4	4	1
2	4	2
6	4	2

Route Table of Node 4:

Destination	Next Hop	Hop Count
1	2	2
3	3	1
5	5	1
2	2	1
6	6	1

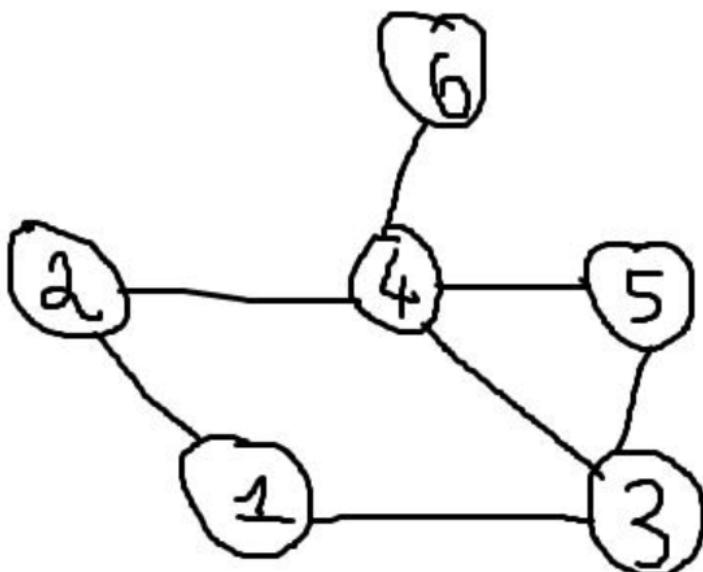
Route Table of Node 5:

Destination	Next Hop	Hop Count
1	3	2
3	3	1
2	4	2
4	4	1
6	4	2

Route Table of Node 6:

Destination	Next Hop	Hop Count
1	4	3
3	4	2
5	4	2
4	4	1
2	4	2

- Answer



6 → 4 → 3 → 1

Ad hoc On-demand Distance Vector routing protocol - AODV

Theory

Note: You can find more documents in Lecture 5

AODV Route request

- Initiated when a node wants to communicate with another node, but does not have a route to that node
- Source node broadcasts a route request (RREQ) packet to its neighbors
- RREQ packet structure

type	flags	resvd	hopcnt
broadcast_id			
dest_addr			
dest_sequence_#			
source_addr			
source_sequence_#			

- Broadcast ID (broadcast_id): is incremented for every RREQ packet sent
- Source/destination address (source_addr, dest_addr): uniquely identifies the RREQ
- Source sequence number (source_sequence): indicates “freshness” of reverse route to the source
- Destination sequence number (dest_sequence) indicates freshness of route to the destination
- When a neighbor receives the RREQ, it will return a route reply (RREP) packet, or forward RREQ to its neighbors
- Receivers can identify and discard duplicate RREQ packets

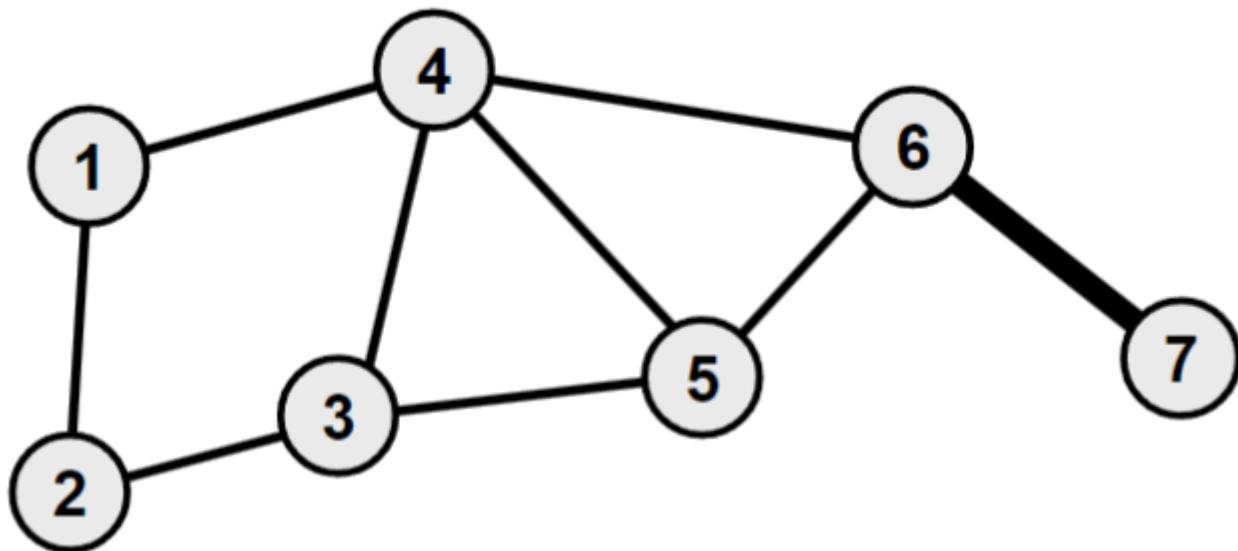
AODV Route Reply

- If a node receives an RREQ packet and it has a current route to the target destination, then it unicasts a route reply packet (RREP) to the neighbor that sent the RREQ packet
- RREP packet structure

type	flags	rsvd	prsz	hopcnt
dest_addr				
dest_sequence_#				
source_addr				
lifetime				

- Source/destination address (source_addr, dest_addr): uniquely identifies the RREP
- Destination sequence number (dest_sequence) indicates freshness of route to the destination
 - (lifetime) or (hop_count): increase in the RREP packet when packet is routed
- Other RREP packets are discarded unless: (destsequence#) number is higher than the previous, or (destinationsequence#) is the same but (hop_cnt) is smaller

(Example) RREQ and RREP from node 1 to node 7

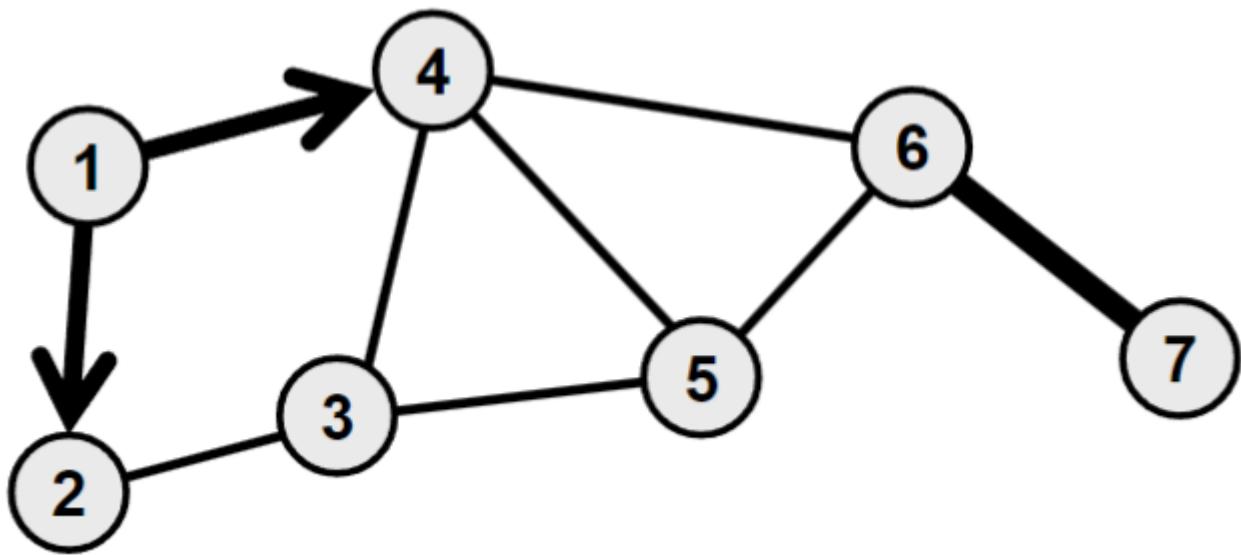


- Node 1 needs to send a data packet to Node 7

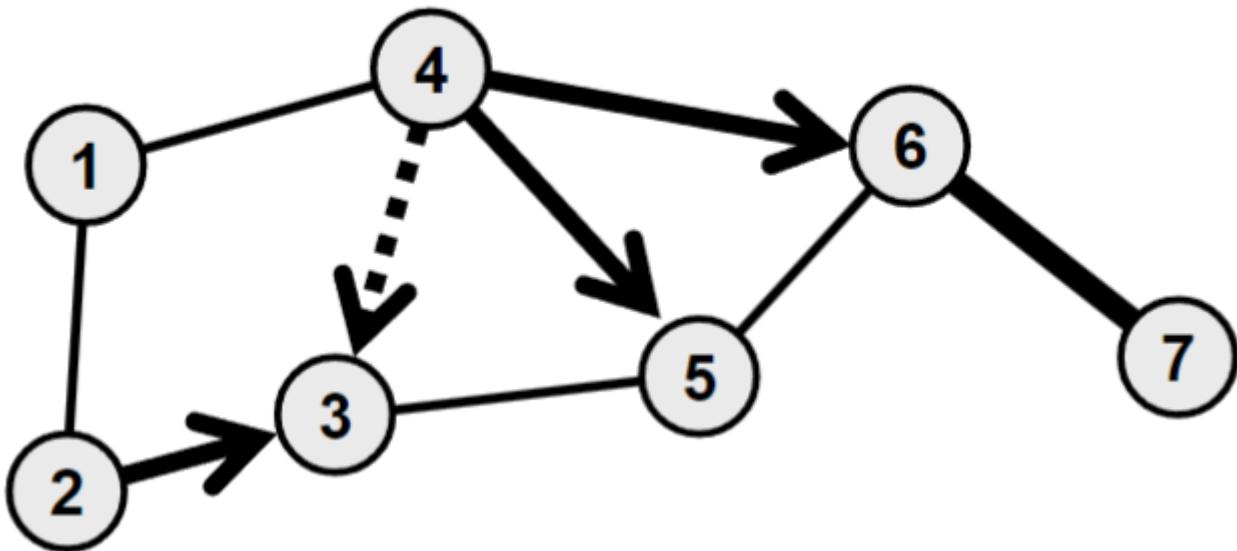
- Assume Node 6 knows a current route to Node 7
- Assume that no other route information exists in the network (related to Node 7)

Routing steps

- **STEP 1**
 - Node 1 sends a RREQ packet to its neighbors
- **source_addr = 1**
- **dest_addr = 7**
- **broadcast_id = broadcast_id + 1**
- **source_sequence_# = source_sequence_# + 1**
- **dest_sequence_# = last dest_sequence_# for Node 7**

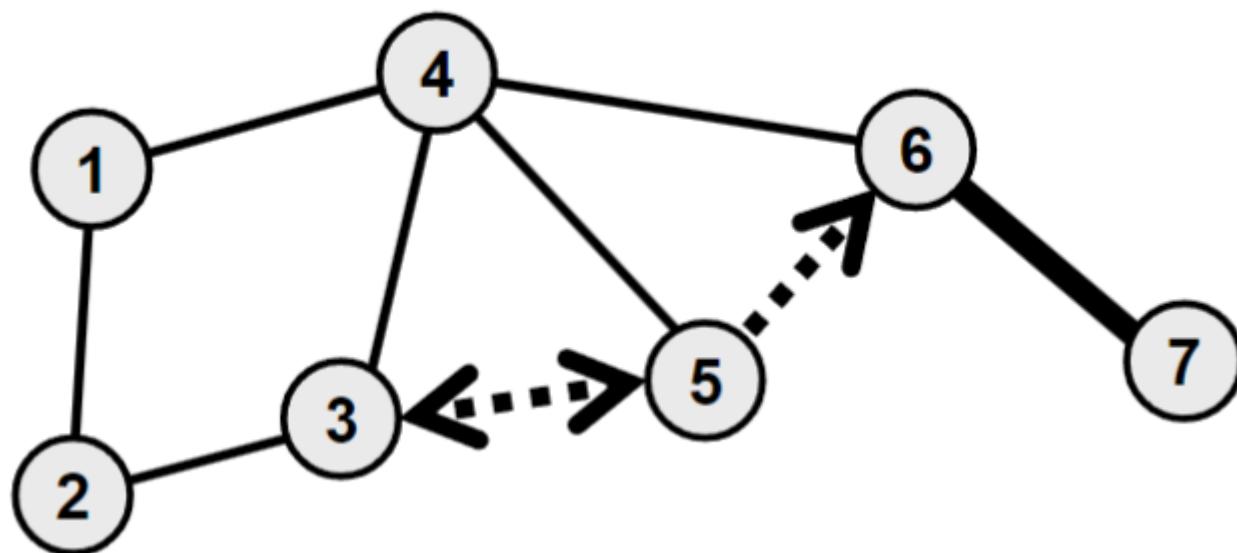


- **STEP 2**
 - Nodes 2 and 4 verify that this is a new RREQ and that the source sequence # is not stale with respect to the reverse route to Node 1
 - Nodes 2 and 4 forward the RREQ
 - Update (source sequence #) for Node 1
 - Increment (hop_cnt) in the RREQ packet



- **STEP 3**

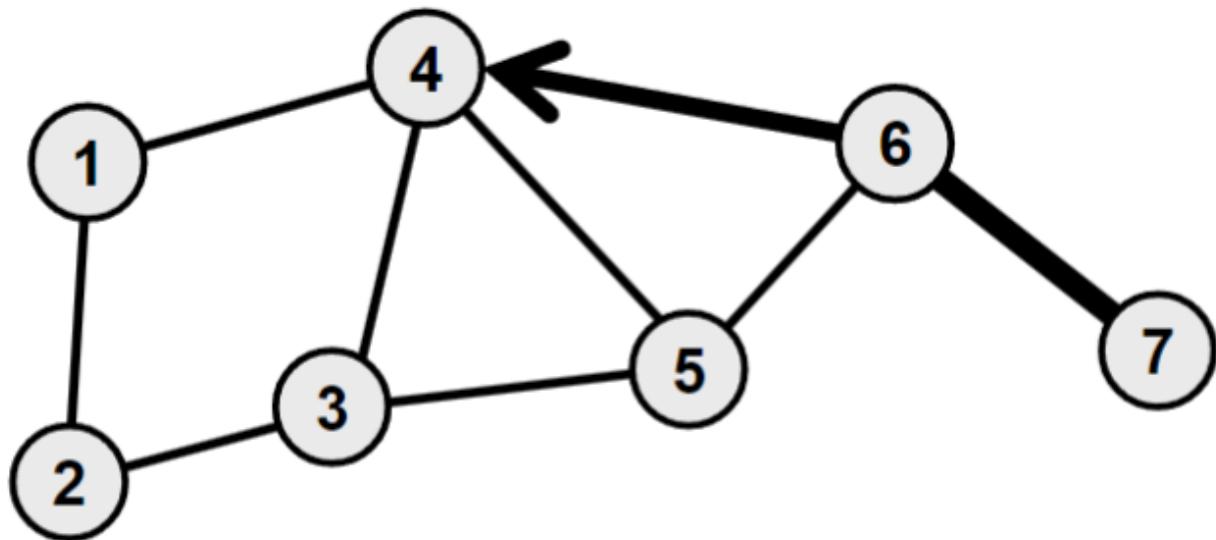
- RREQ reaches Node 6, which knows a route to 7
- Node 6 must verify that the destination sequence number is less than or equal to the destination sequence number it has recorded for Node 7
- Nodes 3 and 5 will forward the RREQ packet, but the receivers recognize the packets as duplicates



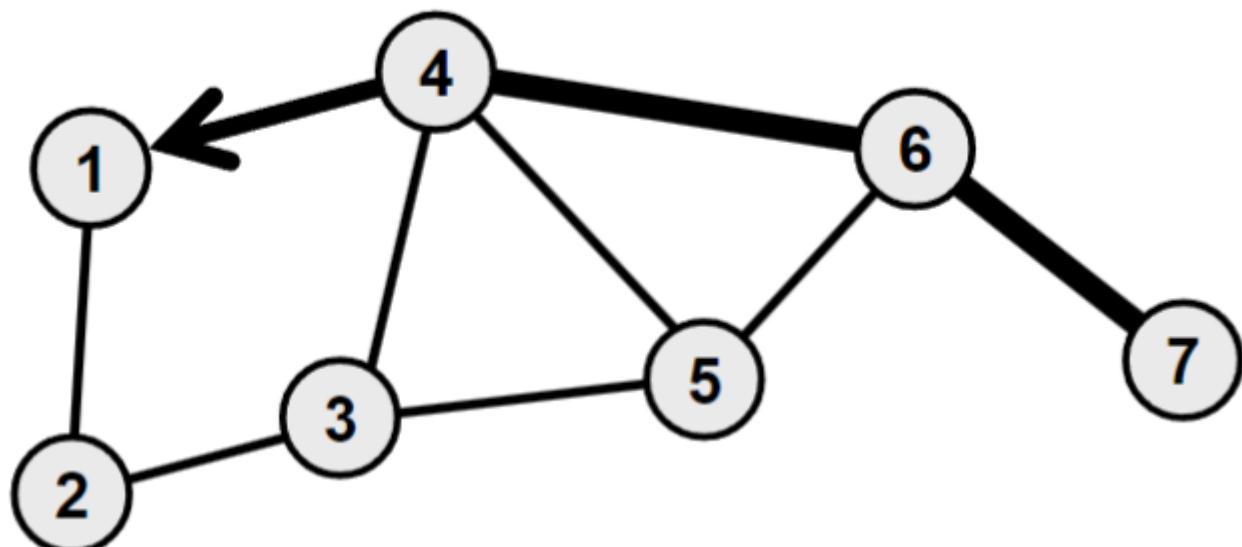
- **STEP 4**

- Node 6 knows a route to Node 7 and sends an RREP to Node 4

- **source_addr = 1**
- **dest_addr = 7**
- **dest_sequence_# = maximum(own sequence number, dest_sequence_# in RREQ)**
- **hop_cnt = 1**

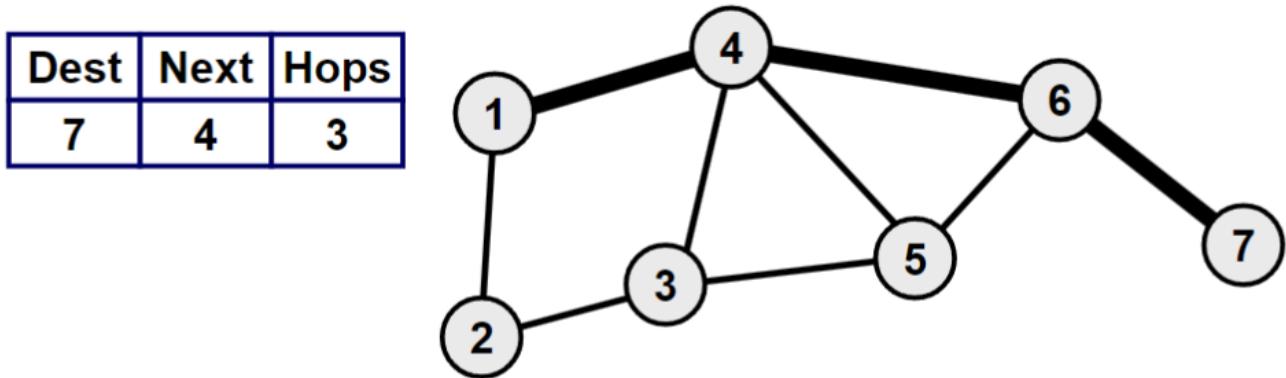


- **STEP 5**
 - Node 4 verifies that this is a new route reply (the case here) or one that has a lower hop count
 - If so, propagates the RREP packet to Node 1 and increases (hop_cnt) in the RREP packet



- **STEP 6**

- Node 1 now has a route to Node 7 in three hops and can use it immediately to send data packets
- Note that the first data packet that prompted path discovery has been delayed until the first RREP was returned



6LoWPAN

Note: You can find documents in Lecture 3

WiFi - 802.11

Note: You can refer to this lecture note [Lecture 17: 802.11 Wireless Networking](#) - University of California San Diego

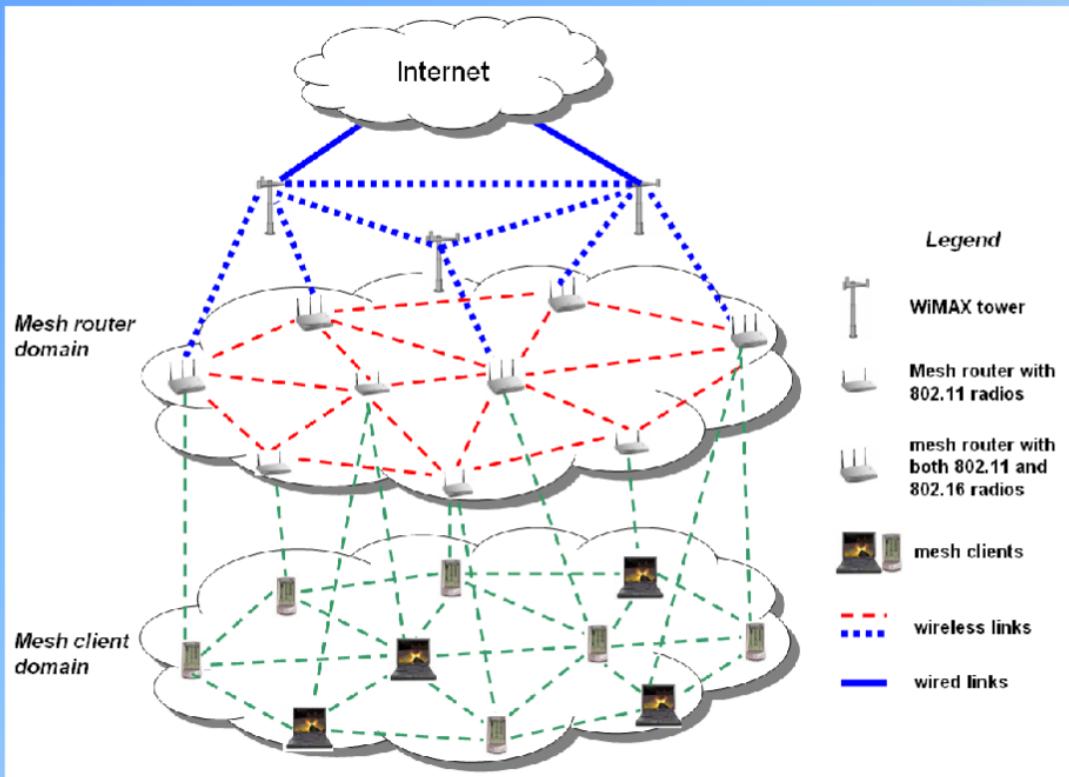
IoTs apps {coap/mqtt/...}, solutions, technologies

Note: You can refer to this lecture note [Lecture 5 - CoAP & MQTT](#) - Universitatea Politehnica din Bucureşti

IoTs architecture/topologies {tree/cluster/grid/chain/...}

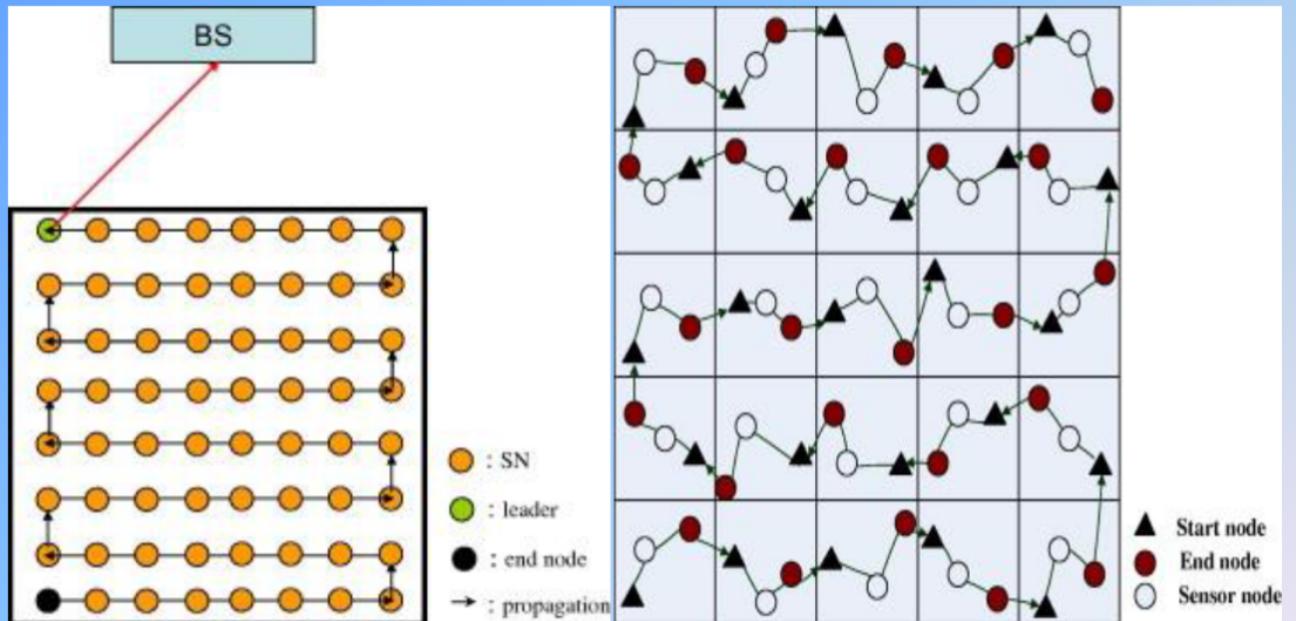
Note: You can find documents in Lecture 4

Cluster Architecture



<http://www.ece.gatech.edu/research/labs/bwn/substation/newArch2.bmp>

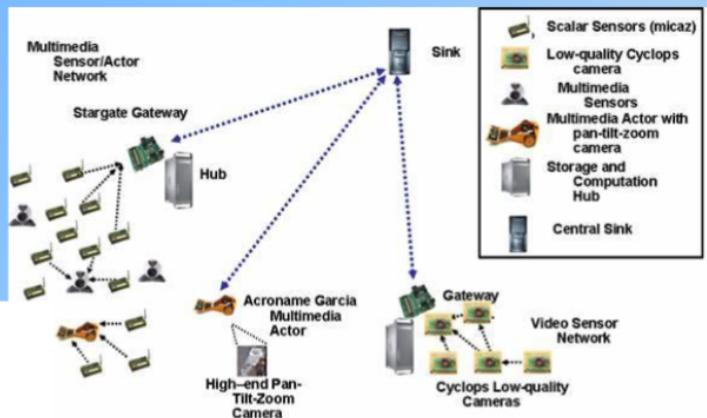
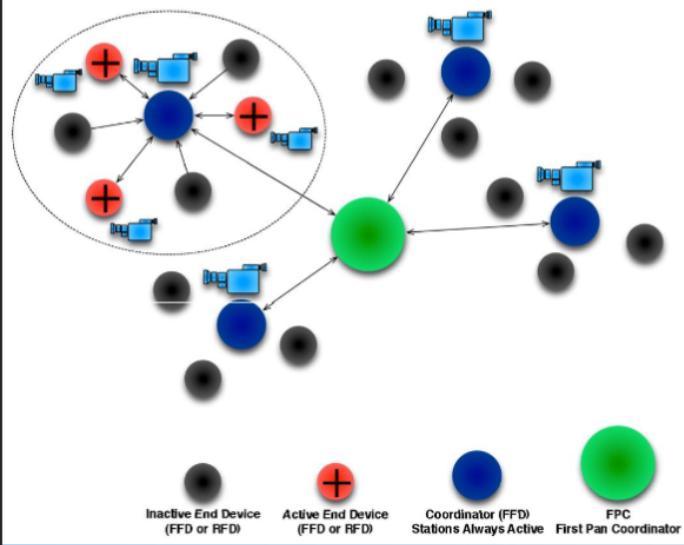
Chain Architecture



Young-Long Chen, and Jia-Sheng Lin, “**Energy efficiency analysis of a chain-based scheme via intra-grid for wireless sensor networks,**” *Elsevier Computer Communications*, Volume 35, Issue 4, 15 February 2012, Pages 507–516

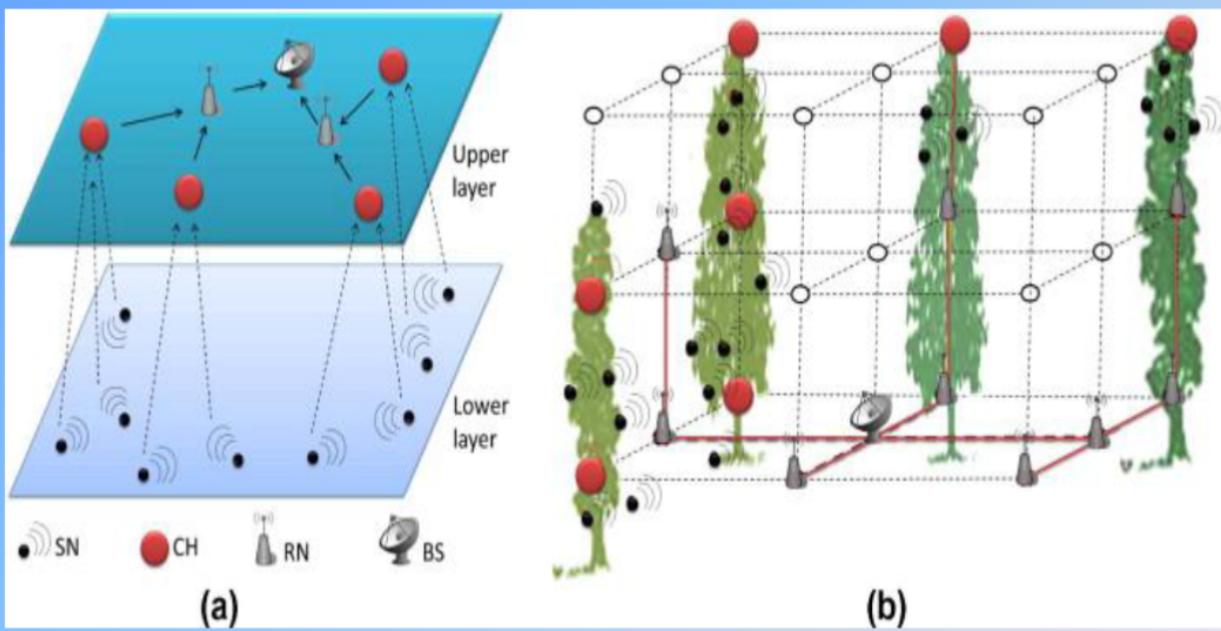
Tree Architecture

[http://www.intechopen.com/source/html/37868/
media/fig9.jpg](http://www.intechopen.com/source/html/37868/media/fig9.jpg)

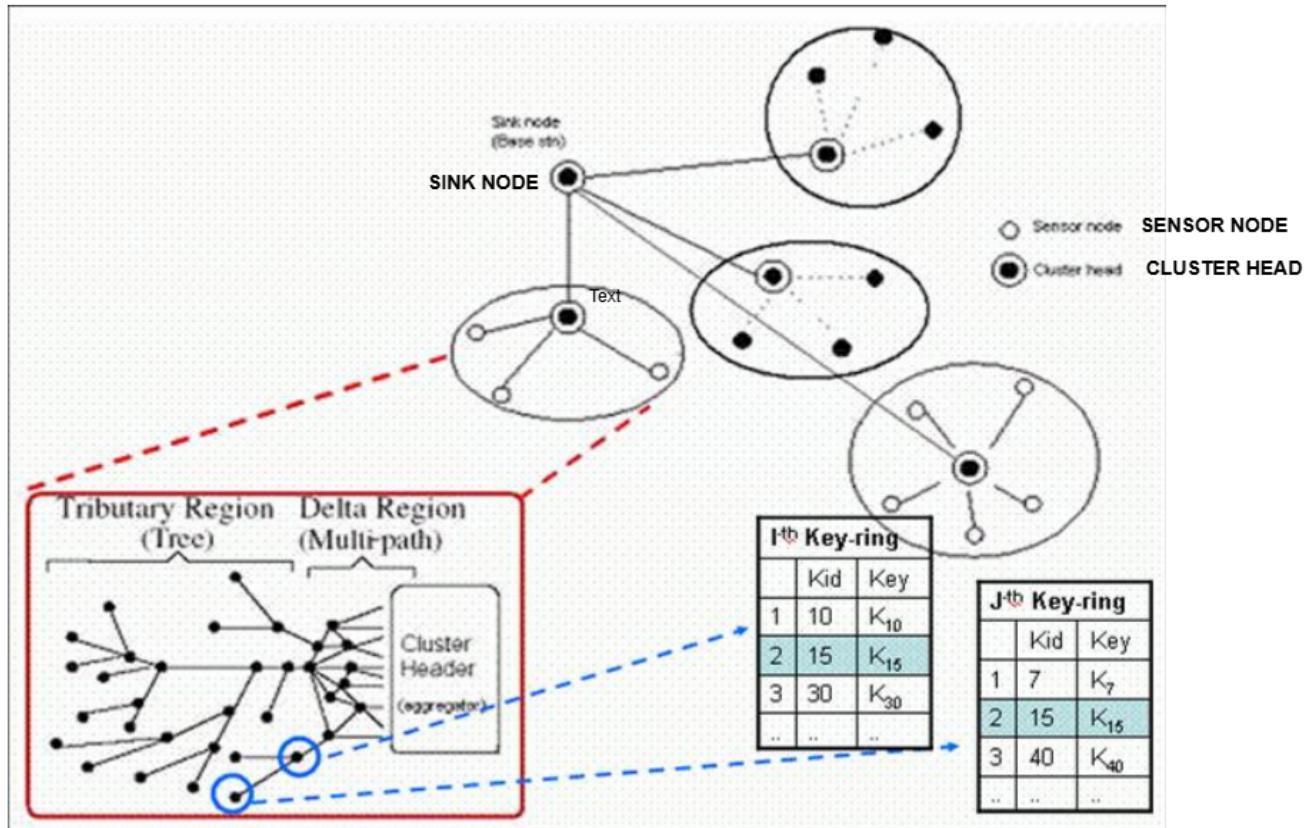


[http://www.ece.gatech.edu/research/labs/bwn/
WMSN/Images/Testbed/testbed.jpg](http://www.ece.gatech.edu/research/labs/bwn/WMSN/Images/Testbed/testbed.jpg)

Grid Architecture



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(그림 3) 클러스터 기반의 Tributaries-Deltas 구조

Source: [Clustered Tributaries-Deltas Architecture for Energy Efficient and Secure Wireless Sensor Network -The KIPS Transactions:PartC | Korea Science](#)