

# Ôn tập NT532 - Công nghệ Internet of Things hiện đại

## ZigBee - 802.15.4

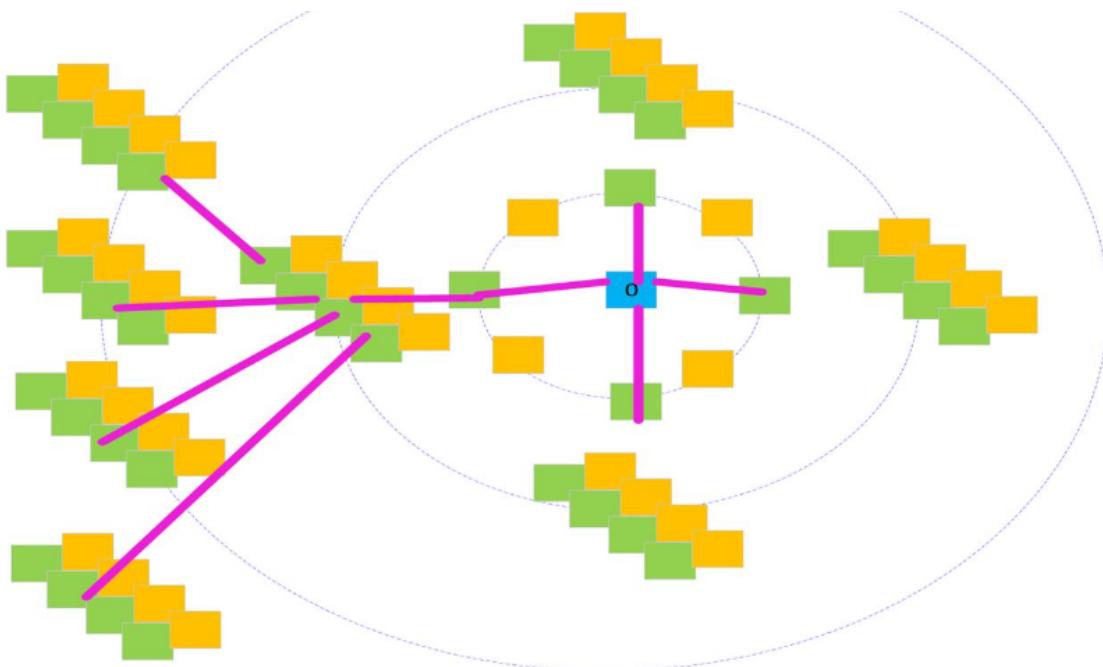
### Theory

*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:
  - $[x + (i - 1) \times A(d + 1) + 1, x + i + A(d + 1)]$
- 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**

$$R_m = 4, D_m = 4, L_m = 3$$

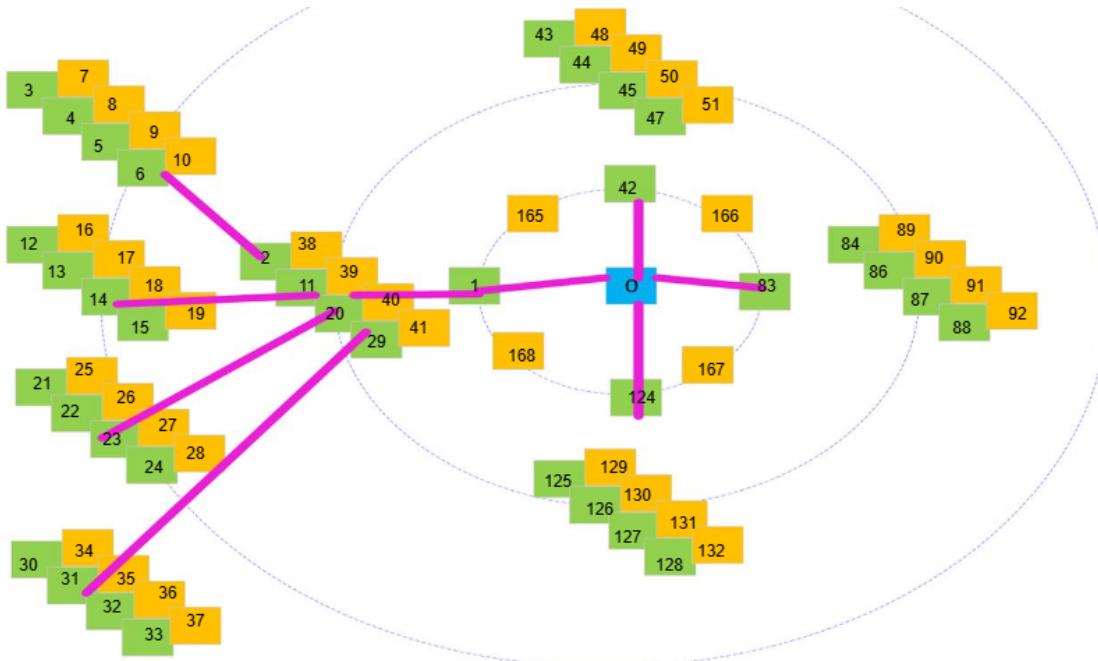


⋮  $R_m=4$ ,  $D_m=4$ ,  $L_m=3$

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

- This topology has four depth levels: 0, 1, 2
- Size of address range for each depth level:
  - $A(2) = 1 + 4 + 4 = 9$
  - $A(1) = 1 + 4 + 4 \times A(1) = 41$
  - $A(0) = 1 + 4 + 4 \times A(0) = 169$
- 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*



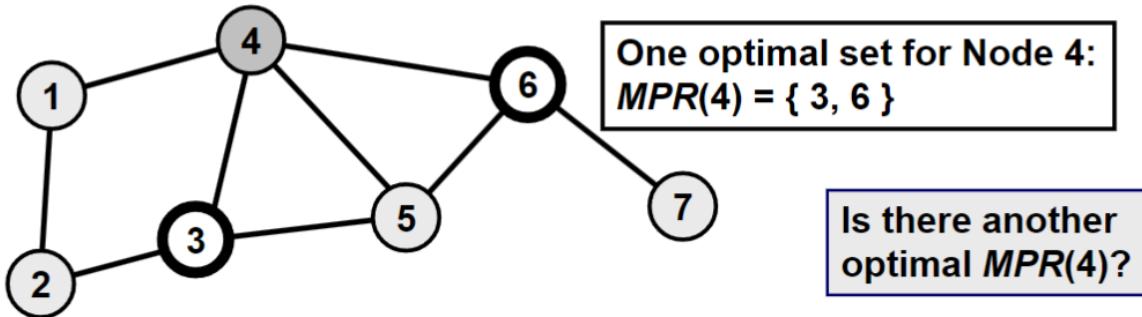
⋮  $R_m=4$ ,  $D_m=4$ ,  $L_m=3$   
 Note BLUE: Coordinator/FFD, Note GREEN: Router/FFD, Note ORANGE: End Device/RFD

## Optimized Link State Routing protocol - OLSR

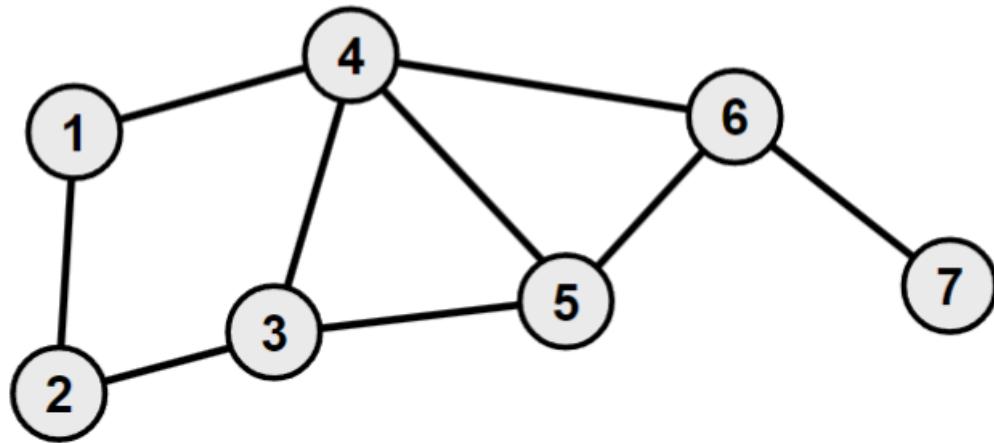
### Theory

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

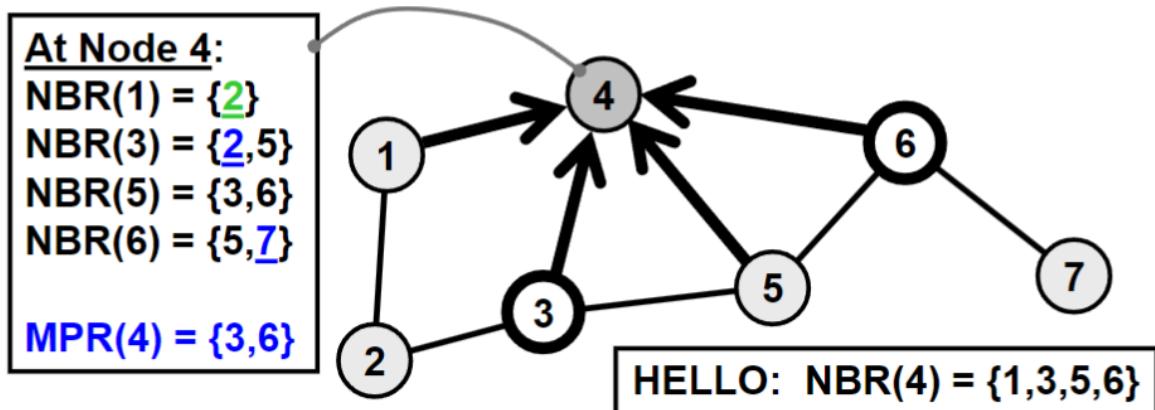


$\text{MPR}(1) = \{ 4 \}$   
 $\text{MPR}(2) = \{ 3 \}$   
 $\text{MPR}(3) = \{ 4 \}$   
 $\text{MPR}(4) = \{ 3, 6 \}$   
 $\text{MPR}(5) = \{ 3, 4, 6 \}$   
 $\text{MPR}(6) = \{ 4 \}$   
 $\text{MPR}(7) = \{ 6 \}$

$\text{MS}(1) = \{ \}$   
 $\text{MS}(2) = \{ \}$   
 $\text{MS}(3) = \{ 2, 4, 5 \}$   
 $\text{MS}(4) = \{ 1, 3, 5, 6 \}$   
 $\text{MS}(5) = \{ \}$   
 $\text{MS}(6) = \{ 4, 5, 7 \}$   
 $\text{MS}(7) = \{ \}$

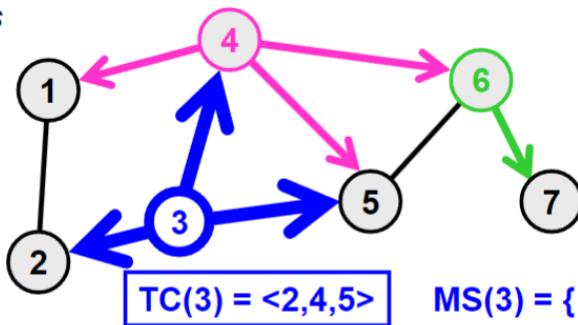
- Neighbor list -  $\text{NBR}(N)$ : a list of nodes that are indicated as node N's neighbors by sending and receiving HELLO message from node N, used to optimize  $\text{MPR}(N)$  NBR set.

- Example at node 4



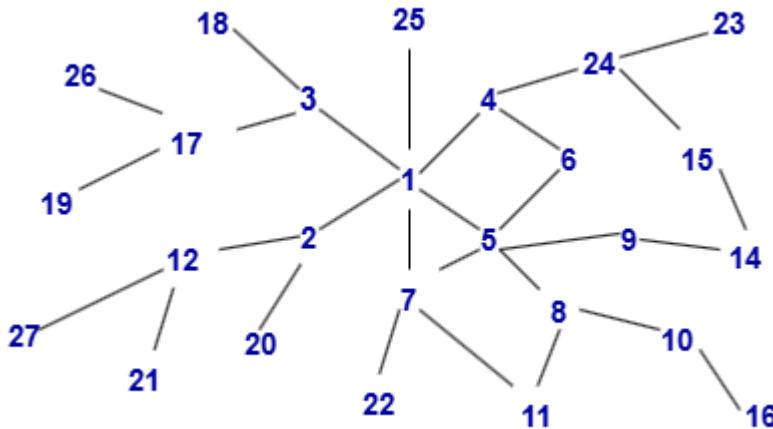
- Topology Control message -  $\text{TC}(N)$ : a list of advertised neighbors (link information) and sequence number (to prevent use of state information). Only MPR nodes generate and propagate TC message
  - Example at node 3

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: MRP(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

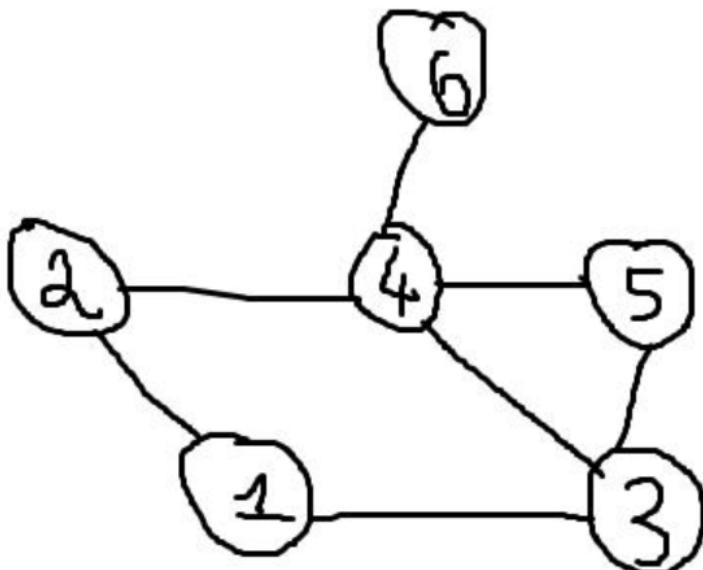
Route Table of Node 5:

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

<b>type</b>	<b>flags</b>	<b>resvd</b>	<b>hopcnt</b>
<b>broadcast_id</b>			
<b>dest_addr</b>			
<b>dest_sequence_#</b>			
<b>source_addr</b>			
<b>source_sequence_#</b>			

- 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

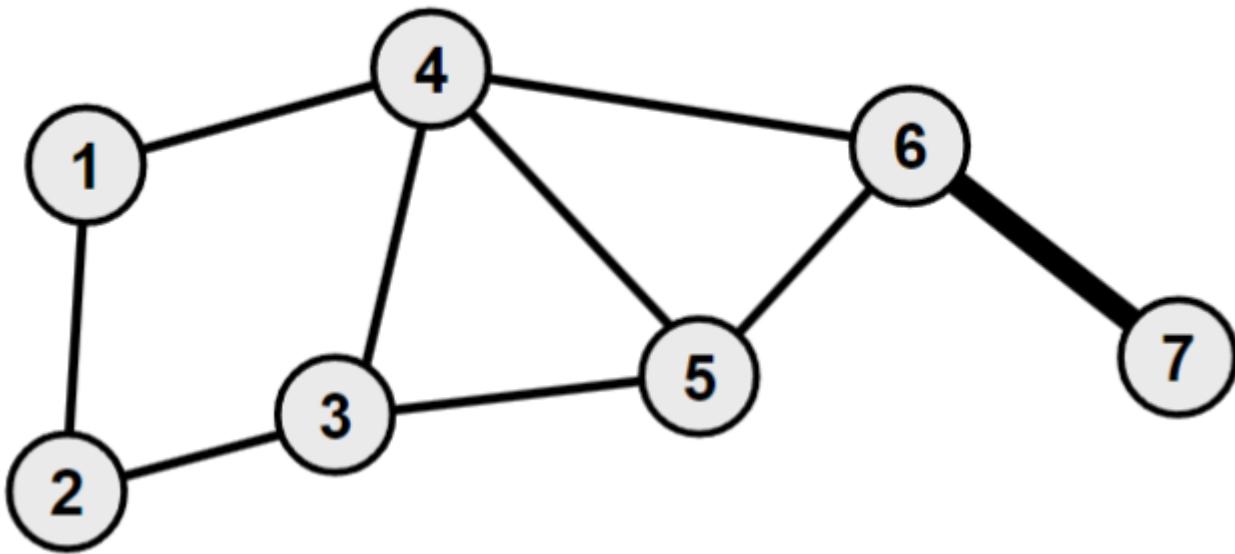
- If a node receives an RREQ packet and it has a current route to the target destination, then it unicasts a route reply packet (RREP) to the neighbor that sent the RREQ packet
- RREP packet structure

<b>type</b>	<b>flags</b>	<b>rsvd</b>	<b>prsz</b>	<b>hopcnt</b>
<b>dest_addr</b>				
<b>dest_sequence_#</b>				
<b>source_addr</b>				
<b>lifetime</b>				

•

- 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

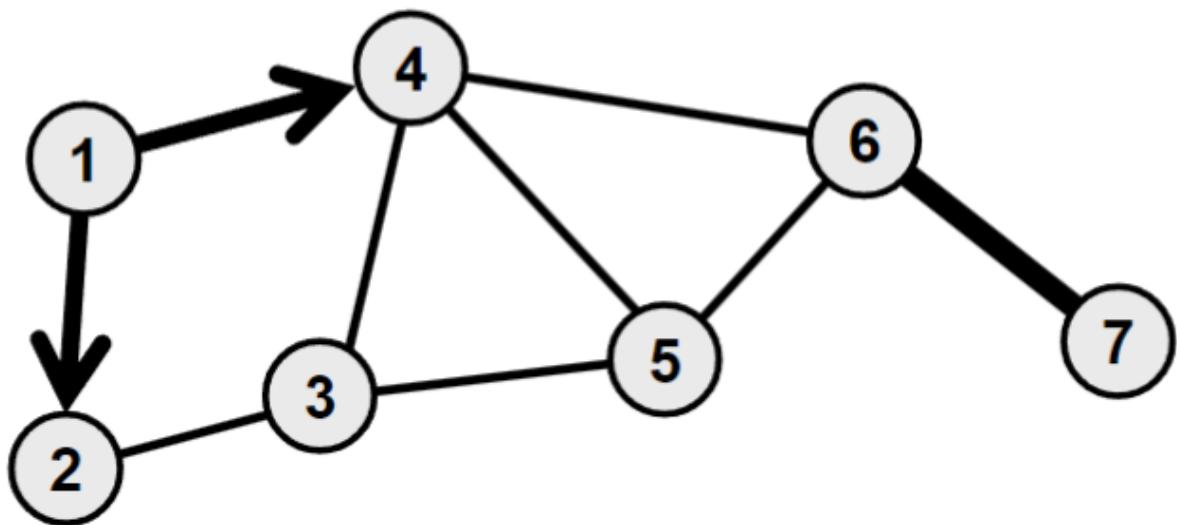
### (Example) RREQ and RREP from node 1 to node 7



- 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

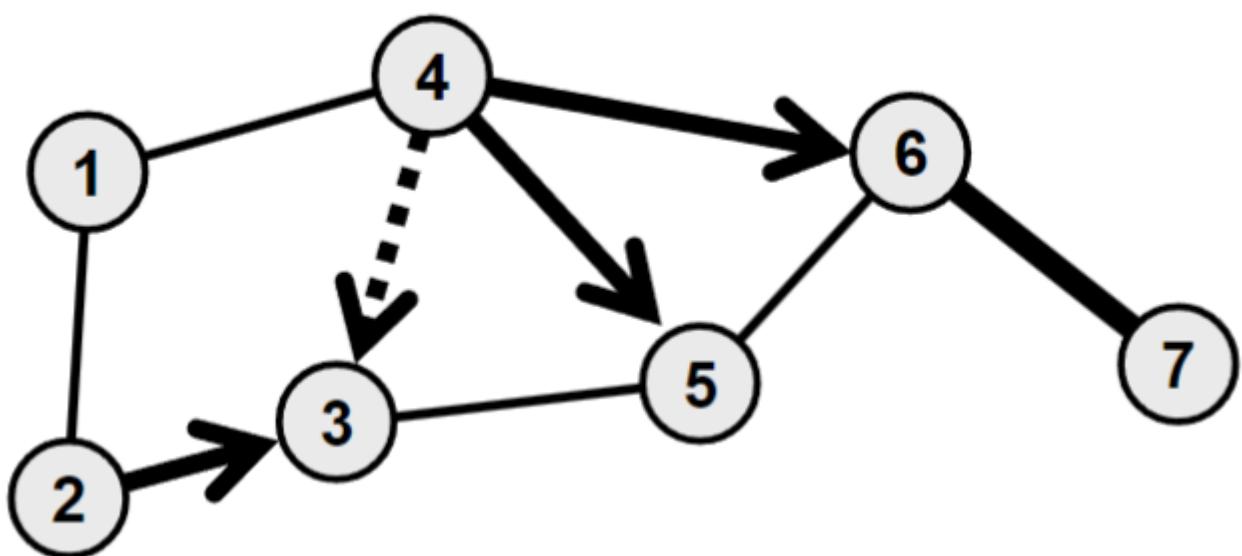
- STEP 1



- 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**

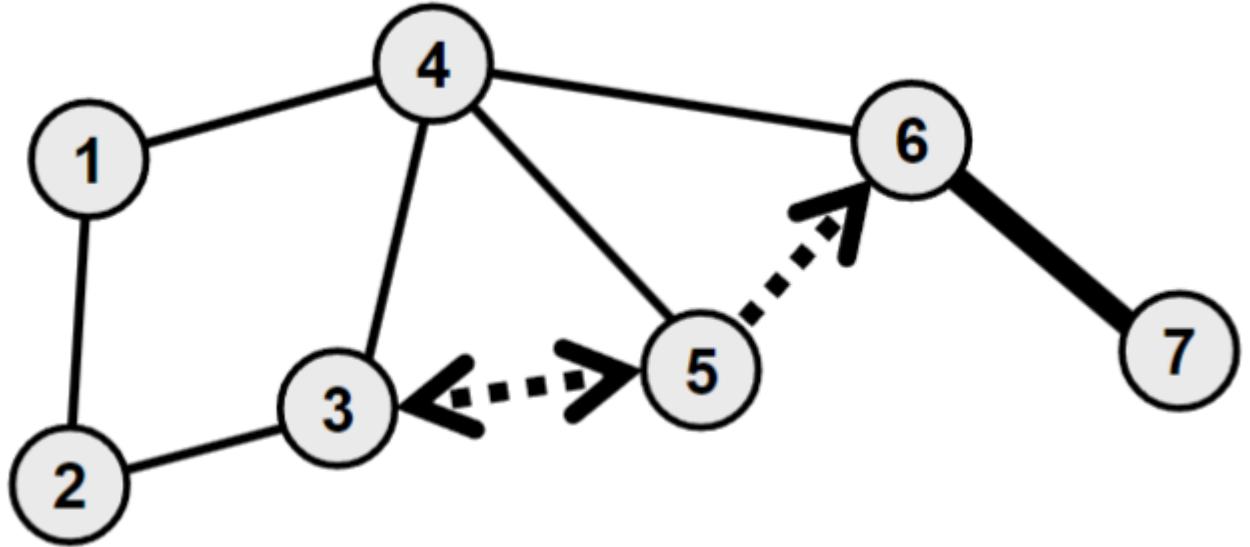
- STEP 2

---

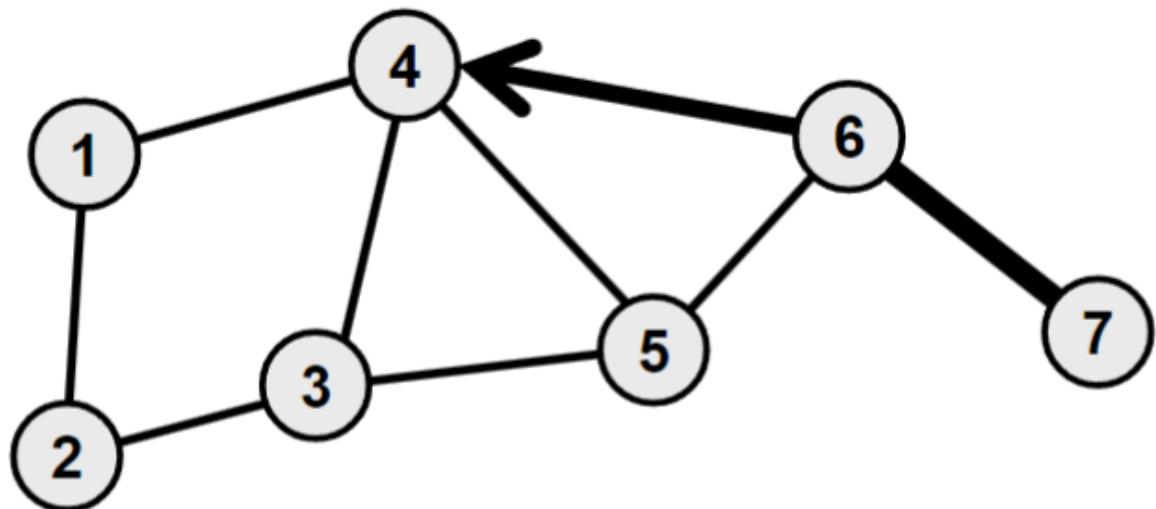


- Nodes 2 and 4 verify that this is a new RREQ and that the source sequence # is not stale with respect to the reverse route to Node 1

- Nodes 2 and 4 forward the RREQ
  - Update (sourcesequence#) for Node 1
  - Increment (hop\_cnt) in the RREQ packet
- **STEP 3**



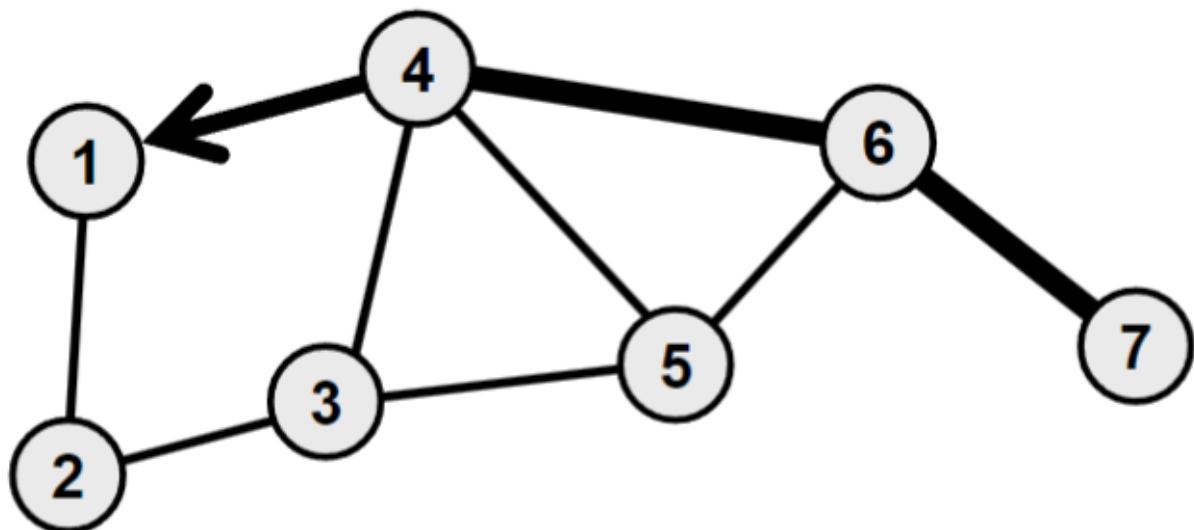
- RREQ reaches Node 6, which knows a route to 7
- Node 6 must verify that the destination sequence number is less than or equal to the destination sequence number it has recorded for Node 7
- Nodes 3 and 5 will forward the RREQ packet, but the receivers recognize the packets as duplicates
- **STEP 4**



- 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**

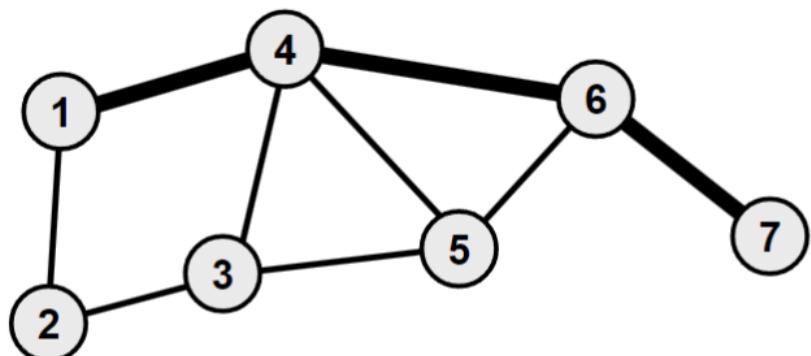
- **STEP 5**



- 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**

Dest	Next	Hops
7	4	3



- 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*

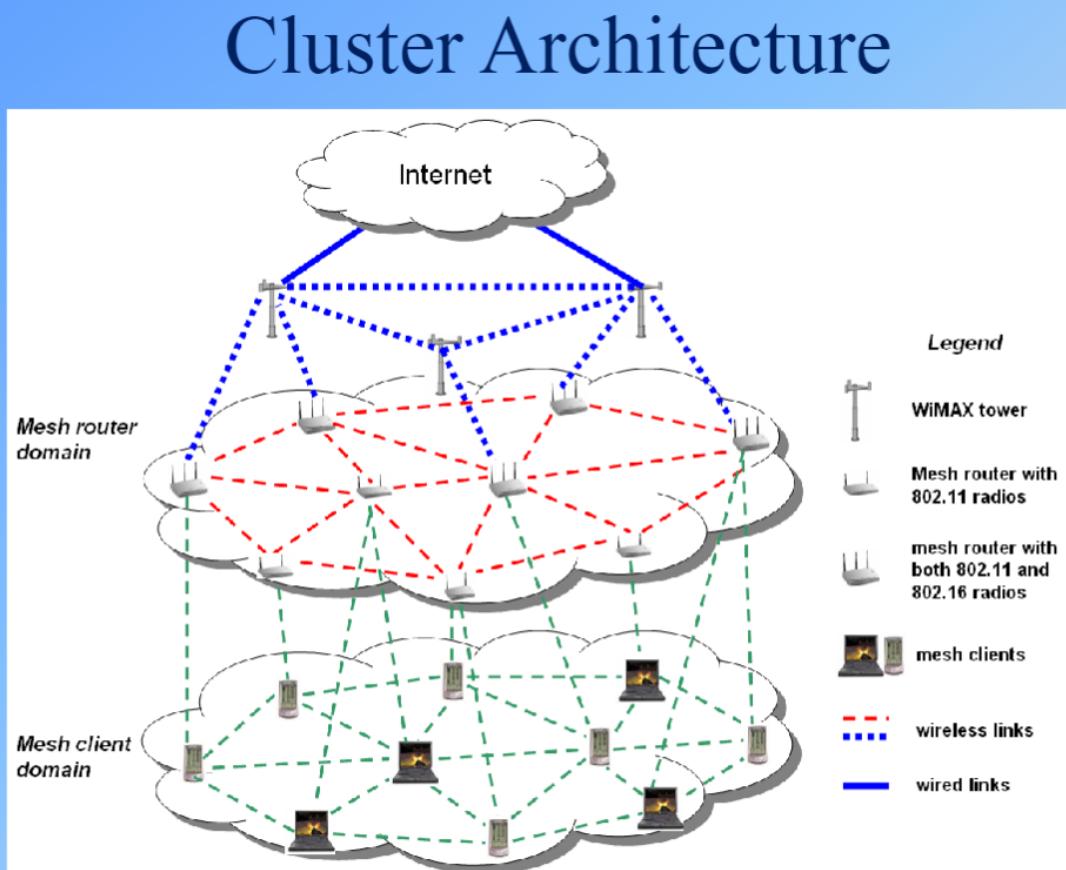
## IoTs apps {coap/mqtt/...}, solutions, technologies

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

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

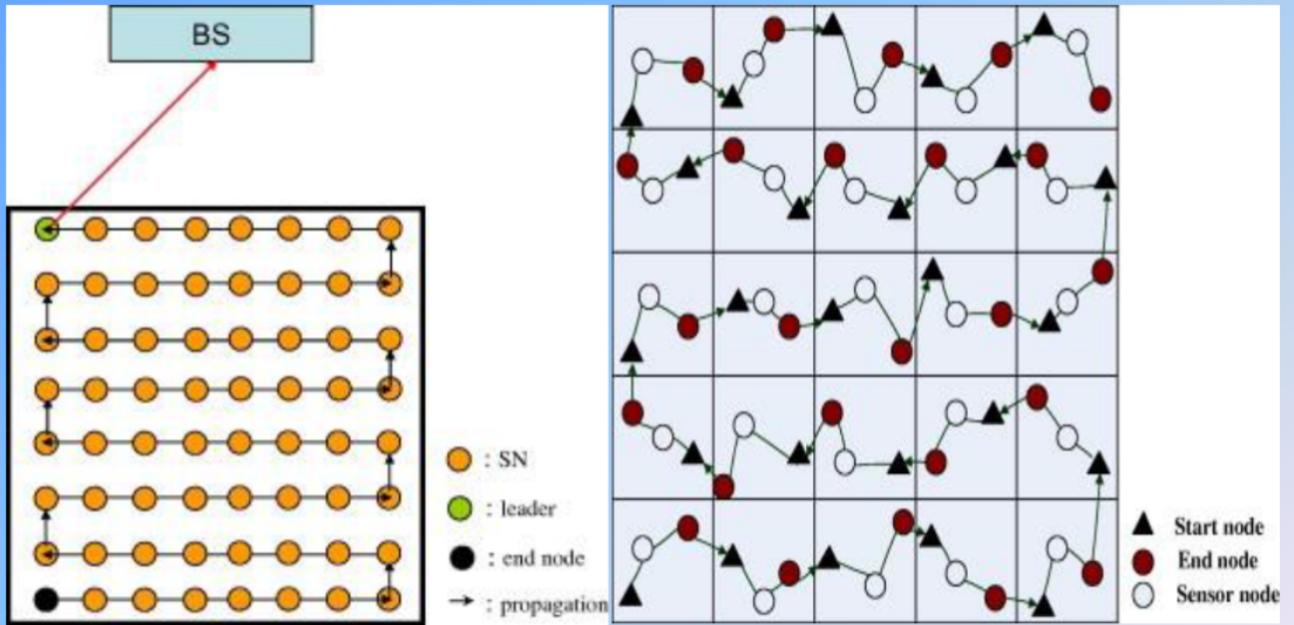
*Note: You can find documents in Lecture 4*

Cluster Architecture



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

## Chain Architecture

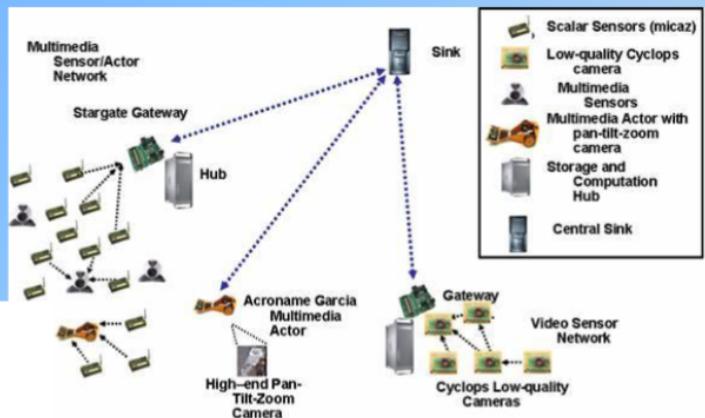
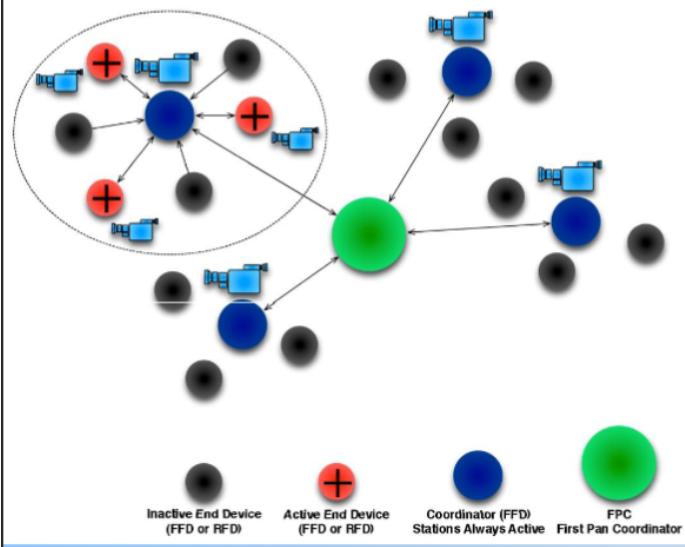


Young-Long Chen, and Jia-Sheng Lin, “**Energy efficiency analysis of a chain-based scheme via intra-grid for wireless sensor networks,**” *Elsevier Computer Communications*, Volume 35, Issue 4, 15 February 2012, Pages 507–516

## Tree Architecture

# Tree Architecture

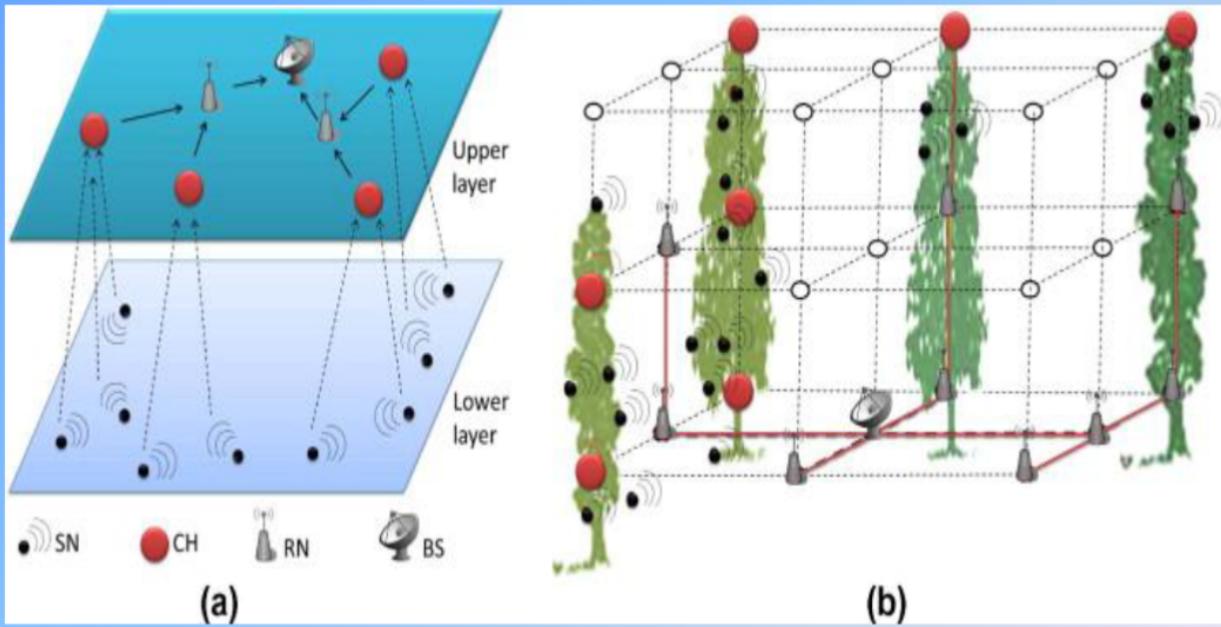
[http://www.intechopen.com/source/html/37868/  
media/fig9.jpg](http://www.intechopen.com/source/html/37868/media/fig9.jpg)



[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

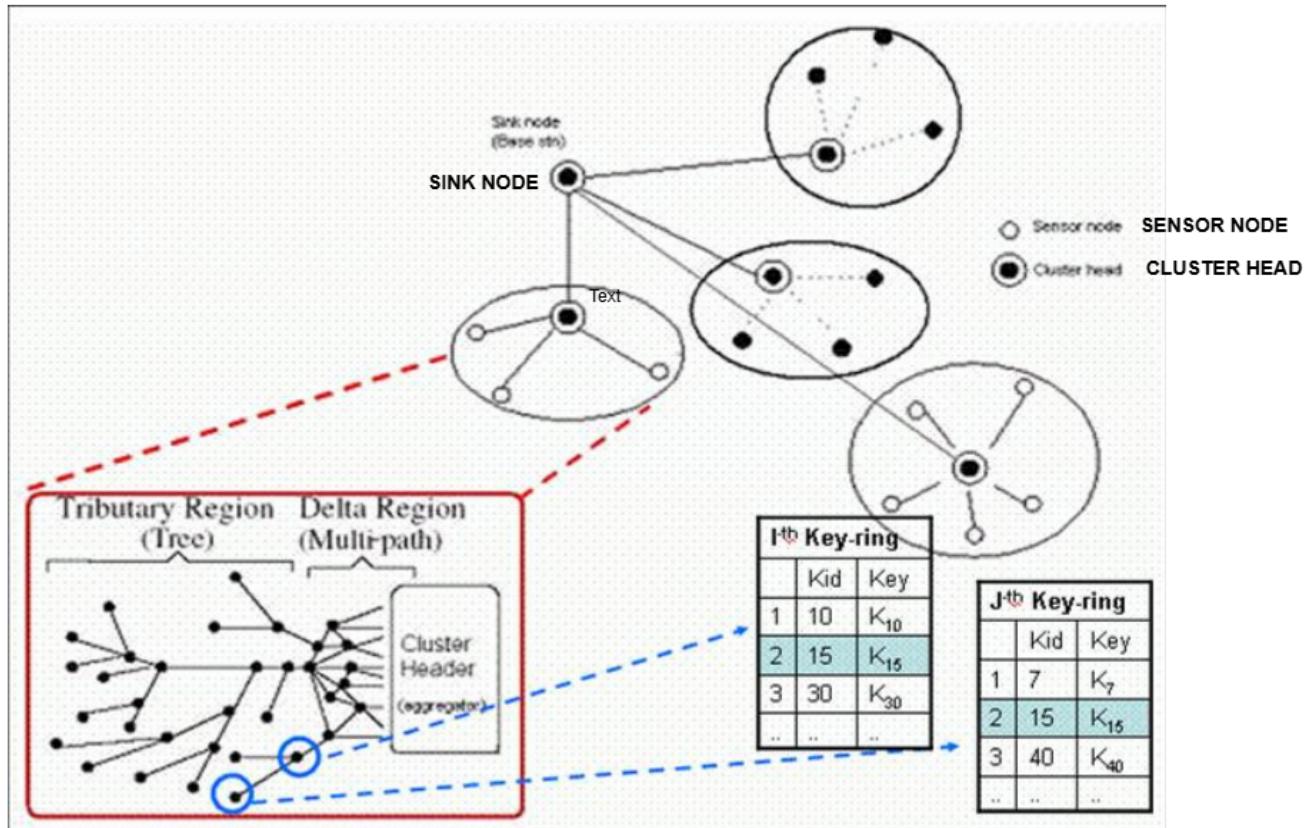
# Grid Architecture



<http://ars.els-cdn.com/content/image/1-s2.0-S0140366412003106-gr1.jpg>

## Tributary-Delta Architecture

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



(그림 3) 클러스터 기반의 Tributaries-Deltas 구조