Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Response to the call for preliminary proposal to TG10]
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Re: [Call for Preliminary Proposals.]

Abstract: [This contribution presents a preliminary proposal for the TG10.]

Purpose: [Preliminary proposal to TG10.]

Hierarchical Mesh Tree Routing

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Outline

This proposal includes the following features:

- Hierarchical Mesh Tree formation, maintenance update
- HMT Routing
- High reliability
- Data aggregation

Typical Use cases

- Smart metering
- Environment monitoring
- Structure monitoring
- Parking monitoring

Motivation

- The current 802.15.4 builds a cluster tree topology
- Data frames can only be sent between device and coordinator
- Even when a routing protocol is applied from the upper layer, it is constrained at the MAC layer by the cluster tree topology
- The D2D function in 15.4m allows devices associated to the same coordinator to send packets to each other directly but does not provide routing capability to distant nodes

HMT formation

- Each node is required to associate with a coordinator after performing an active or passive scan as described in Section 5.1.3.1 of IEEE Std 802.15.4-2011
- Each node has a depth representing the distance of that node to the root of the tree (PAN coord) in number of hops
- The depth of the root is 0
- The depth of a coordinator is carried in the association response frame
- After association, the depth of a node is initialized to the depth of its coordinator + 1.
- Once associated, a node starts to broadcast enhanced beacons(EB) periodically

HMT formation (2)

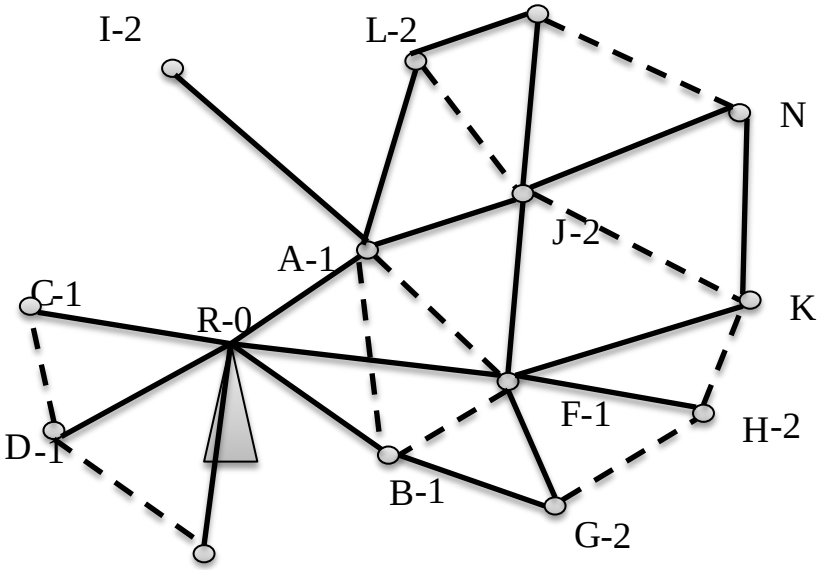
- A node holds a neighbor table filled based on the information contained in the EBs

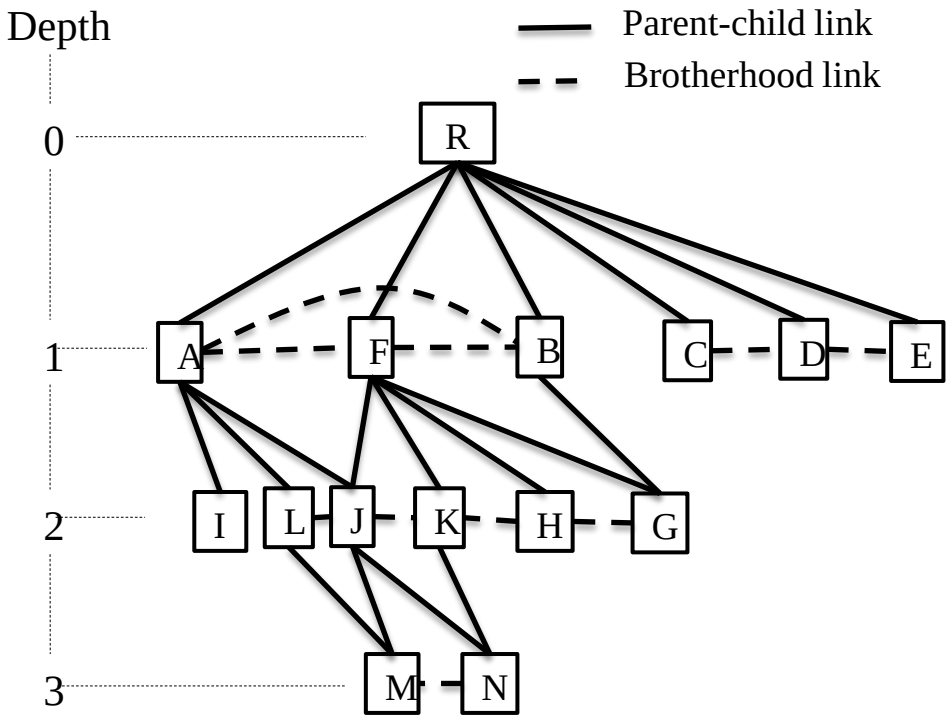
Neighbor ID	Neighbor Depth	Metric 1	…	Metric n

- A neighbor is categorized according to its depth. If the depth of a node M is D_M and the depth of a neighbor N is D_N
  - If $D_M > D_N$ ➔ N is a parent
  - If $D_M = D_N$ ➔ N is a brother
  - If $D_M < D_N$ ➔ N is a child
- A node starts filling up its neighbor table only after association. It ensures that only nodes from the same PAN are recorded as neighbors
- After the HMT formation, a node can join the network by performing an active or passive scan. The node shall associate with the neighbor with the lowest depth. After association, it fills up its neighbor table according to the other beacons received

HMT formation (3)

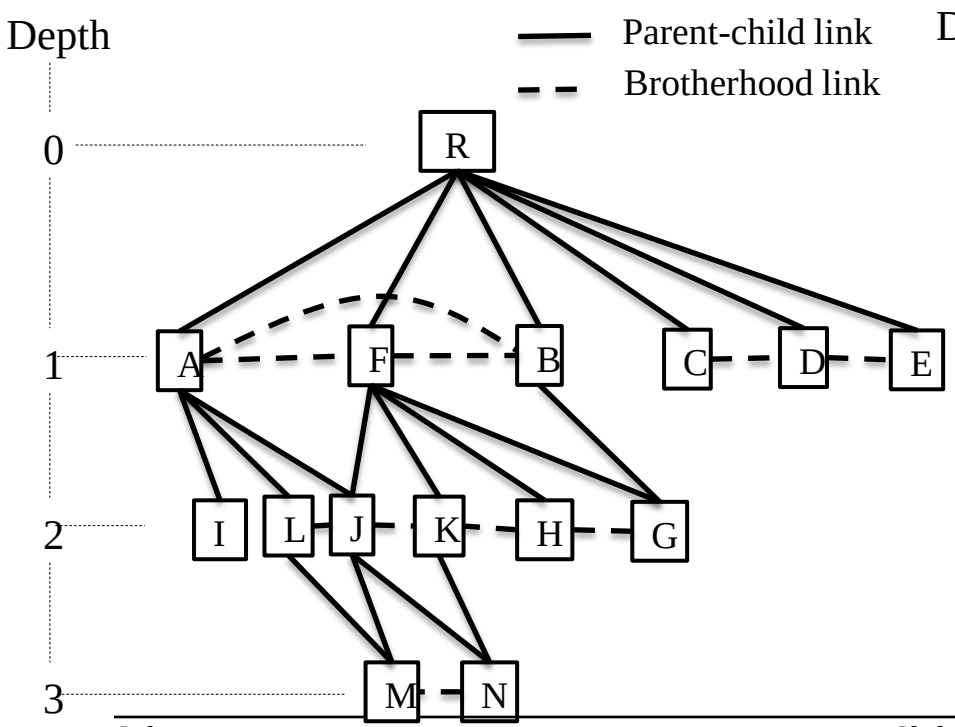
- The HMT formation time is the time required to have every nodes of the network associated to the PAN
- Example of a HMT

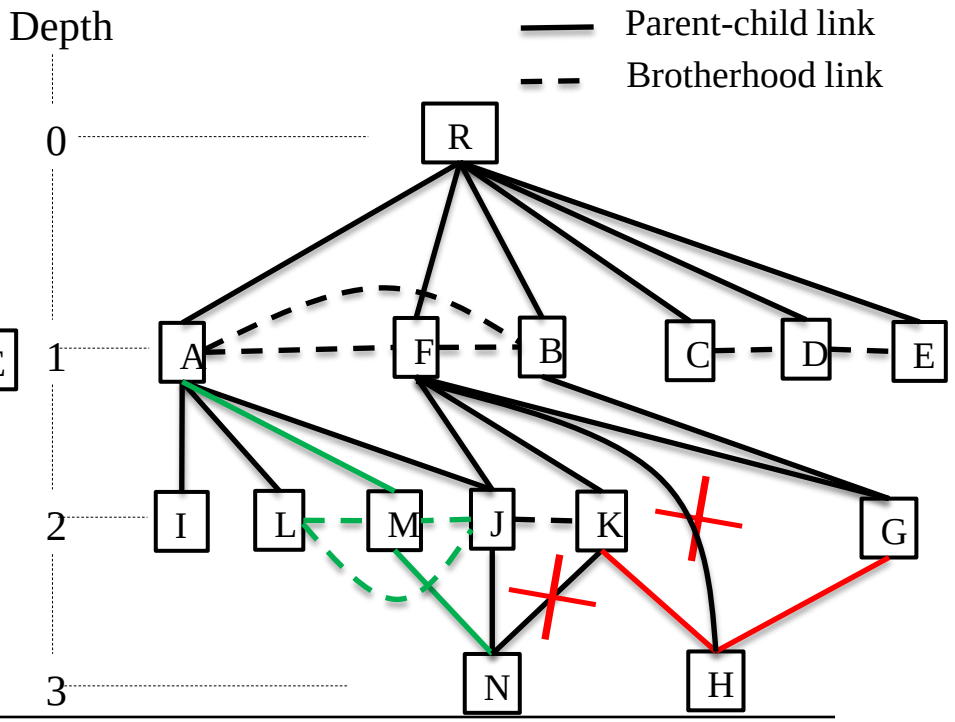




HMT maintenance and update

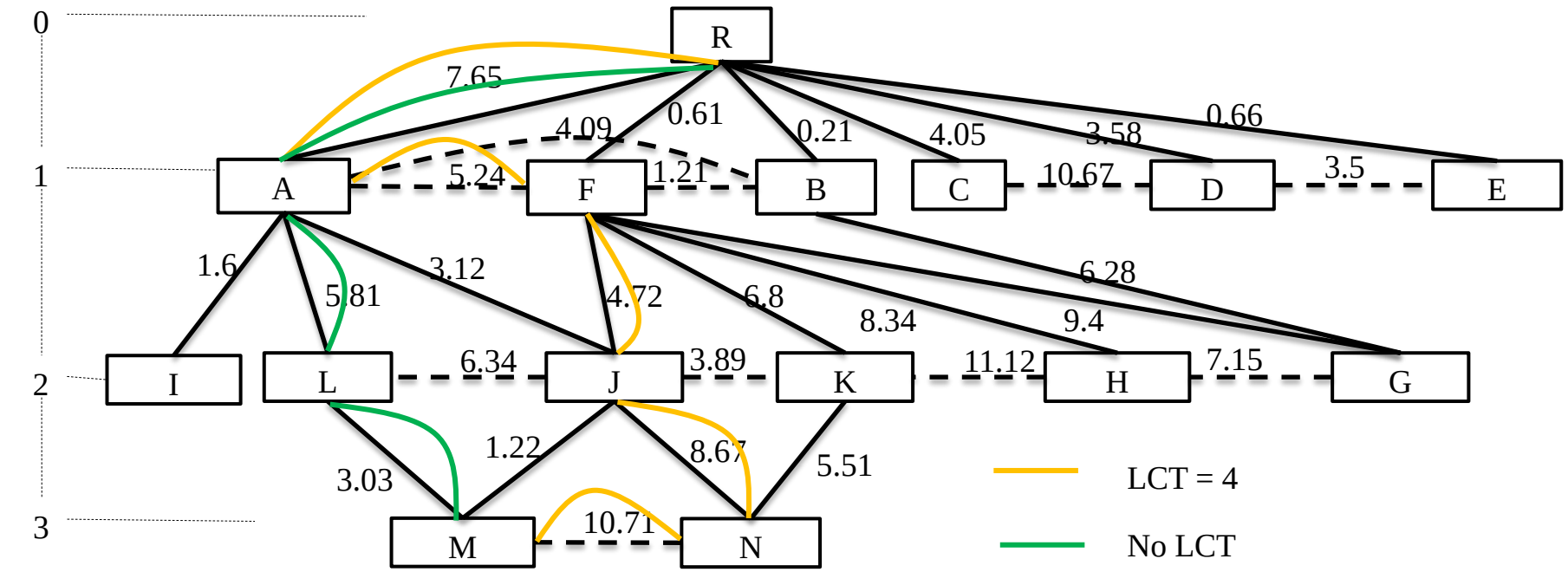
- The neighbor table is maintained through periodic beacon broadcasts
- A node's depth and the neighbor table is updated according to the changes in the network reflected by the presence/absence of beacons
- If a node is disassociated to its coordinator, it either tries to re-associate or tries to associate with another parent in the neighbor table.





HMT Routing (MP2P)

- Link cost-based (BER, success rate, latency…)
- Reactive routing through parents and/or brothers with priority given to the parents through a Link Cost Threshold (LCT) set by the PAN coord regarding the chosen metric and broadcast in EBs
- A node holds the list of TAs and RAs of a packet with a given SN and SA. In order to avoid loops, a node shall select a next hop that is not in that list. The list shall be erased after a TBD time



HMT Routing (P2MP)

- When a node receives a packet to forward or a beacon, it fills a routing table

Destination	Next Hop	Metric 1	…	Metric n
Node originating the frame	Node from which I received the frame			

- Example of routing table at R

Destination	Next Hop	SINR
A	A	7.65
F	F	0.61
…	…	…
F	A	7.65
L	A	7.65
M	A	7.65
…	…	…

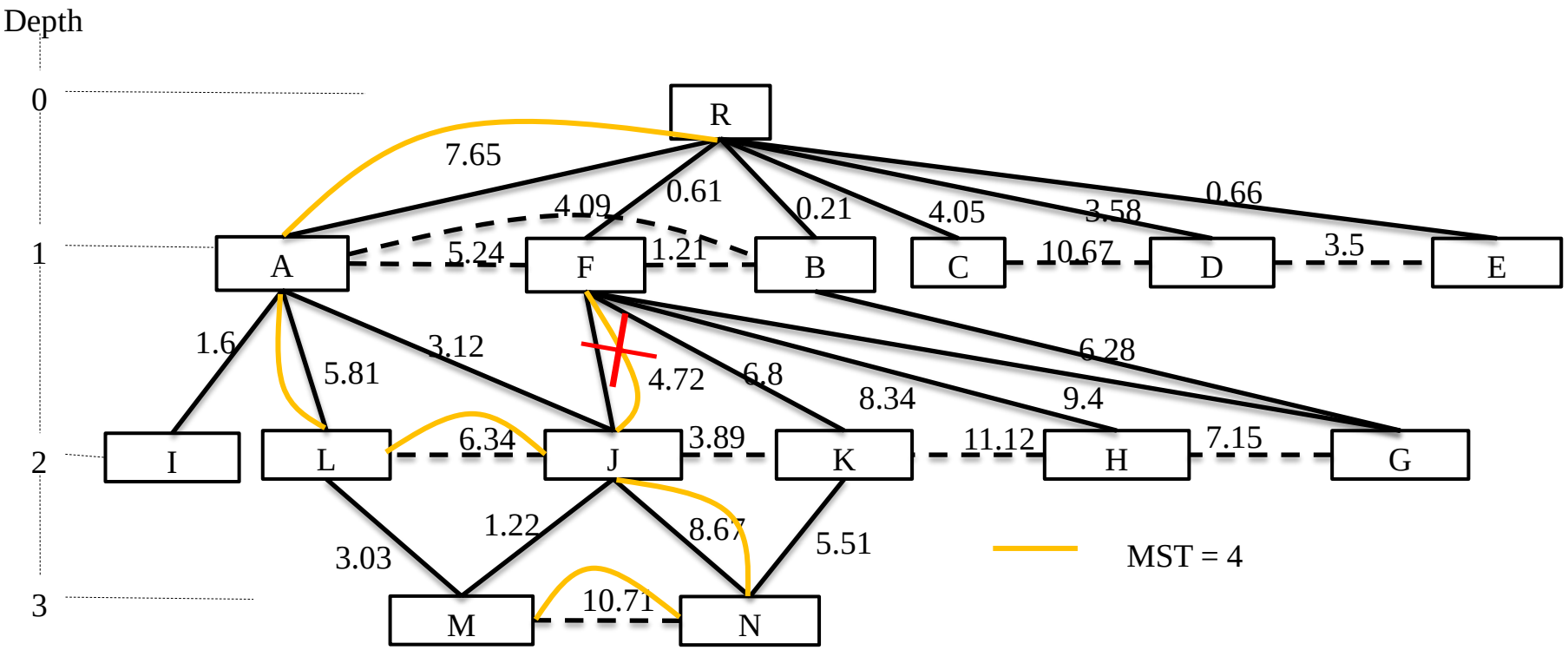
Entries from the beacons

Entries from data packets

- A packet is routed through the next hop with the best metric

High reliability option

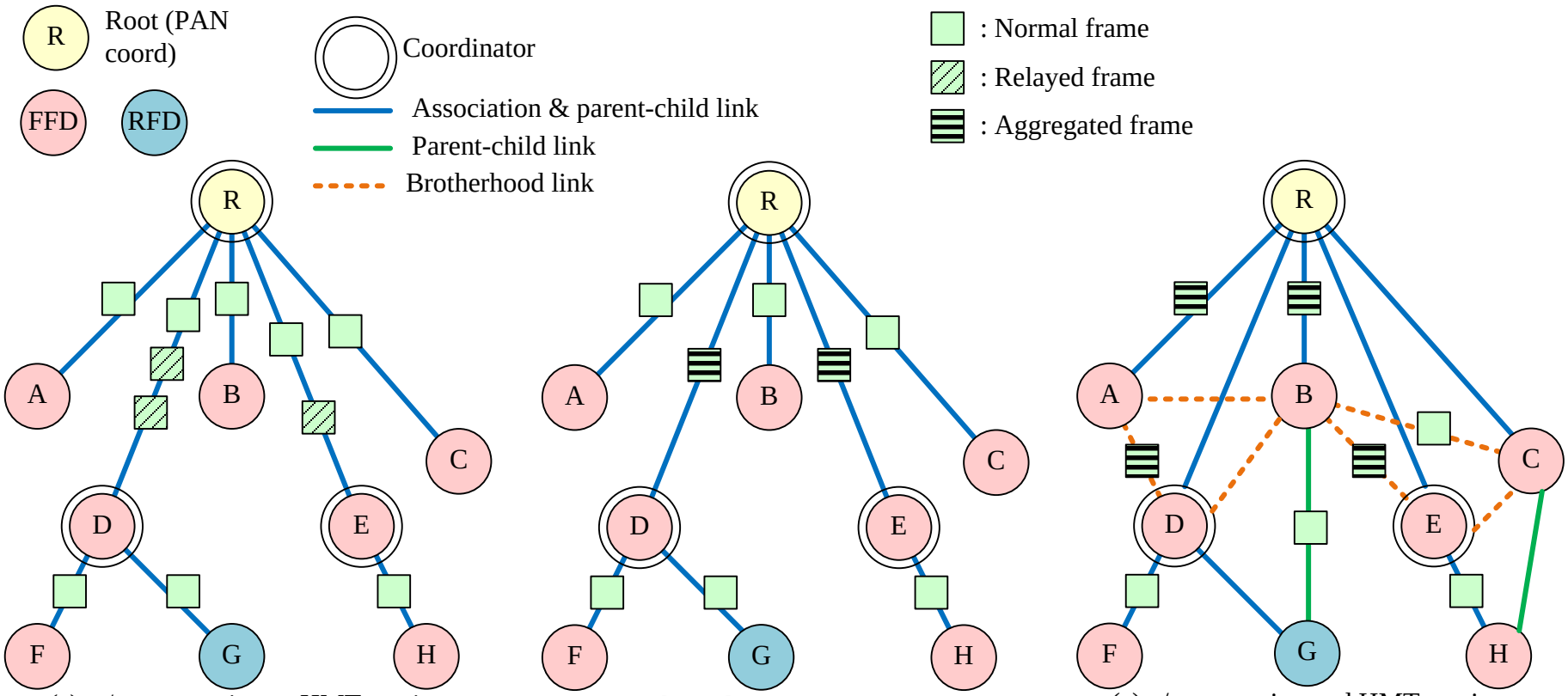
- If the high reliability option is on, the AR field must be set to 1. If an acknowledgment is not received after a packet transmission, the packet is forwarded through another neighbor



Data aggregation (1)

- A node aggregates the packets collected from its neighbors with its own packet before forwarding them.
- Reduce collisions
- Reduce the bottleneck effect as we get closer to the root of the tree
- The number of aggregated packets is limited by the maximum size of a frame

Data aggregation (2)



(a) w/o aggregation or HMT routing

(b) Only w/ aggregation

(c)w/ aggregation and HMT routing

HMT Routing IE

Bit: 0 - 6	7 - 14	15	Octets: Variable
Length	Element ID	Type = 0 (Header)	IE content

Octets : 1	0/Variable	Bits: 0	1	2	3-6	7	Octets: variable	…	Octets: variable
Depth	Addressing fields	High reliability (B - C)	Data aggregation (B - C)	Flow (0: Up, 1: Down)	Number N of metrics (B - C)	Reserved (B - C)	Metrics 1 (B -C)	…	Metrics N (B -C)

Octets: 0/2	0/2/8	0/2	0/2/8
Final Destination PAN ID (D)	Final Destination address (D)	Origin Source PAN ID (D)	Originl Source address (D)

Bits: 0-3	4-7	0/Variable	0/Variable
Metric ID	Metric Priority	Metric threshold	Metric value

B: field present in a EB
C: field present in a command (ex: association response)
D: field present in a data frame

Data aggregation IE

Bit: 0-10	11-14	15	Octets : variable
Length	Group ID	Type = 1 (Payload)	IE content

Bits: 0-3	6-7	Octets: 1	…	1
Number N of aggregated packets	Reserved	Size of the aggregated packet 1	…	Size of the aggregated packet N

Preliminary results (1)

- Number of nodes: 11x11
- Simulator: Qualnet
- Metric: SINR
  - Packet birth: 2 packets /s

	No LCT	LCT = 3.0	LCT = 7.0
E2E success ratio (%)	49.209	58.948	76.037
Average E2E delay (s)	0.020254	0.023117	0.03998
Average Number of hops	2.142	2.501	4.430

  - Packet birth: 2 packets/5s

	No LCT	LCT = 3.0	LCT = 7.0
E2E success ratio (%)	99.290	98.948	98.753
Average E2E delay (s)	0.017359	0.019462	0.039918
Average Number of hops	2.101	2.356	4.683

Preliminary results (2)

- Number of nodes: 33 x 33
- Metric: SINR
  - Packet birth: 2 packets /s

	No LCT	LCT = 3.0	LCT = 7.0
E2E success ratio (%)	49.851	58.000	80.959
Average E2E delay (s)	0.051	0.059	0.113
Average Number of hops	6.017	7.015	13.054

  - Packet birth: 2 packets/5s

	No LCT	LCT = 3.0	LCT = 7.0
E2E success ratio (%)	84.606	85.037	87.820
Average E2E delay (s)	0.048	0.057	0.105
Average Number of hops	5.627	6.588	12.451

Thank you

Q/A