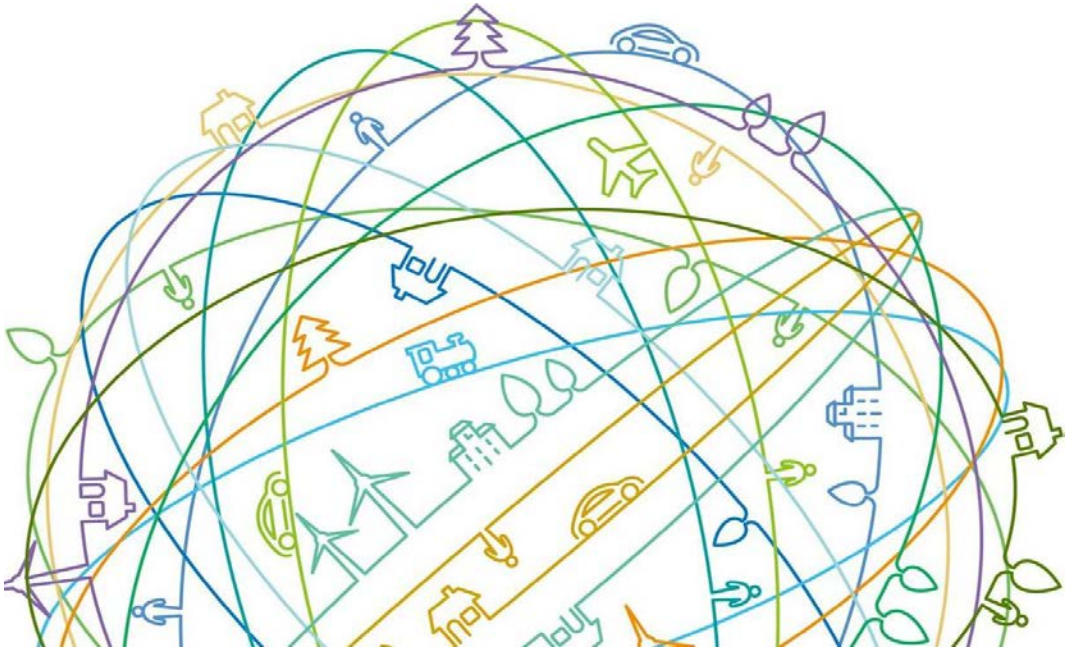
3GPP TSG-RAN WG3 #101bis
Chengdu, China, 8th - 12th October 2018

R3-185404

For Discussion

On the Reliability and Load Balancing in IAB



OMESH Networks Inc.

www.omeshnet.com
www.omeshnet.cn

Objective

9.7.7 Goals of Topological Redundancy

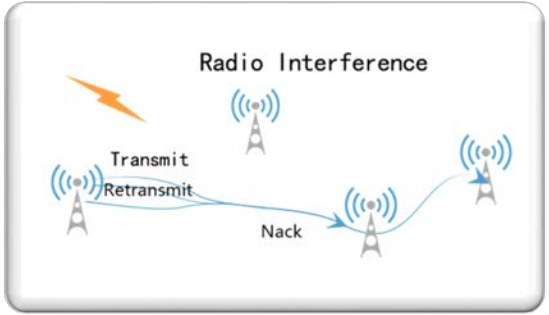
Topological redundancy has the goal to enable robust operation, e.g., in case of backhaul link blockage, and to balance load across backhaul links. Establishment and management of topological redundancy is part of topology adaptation.

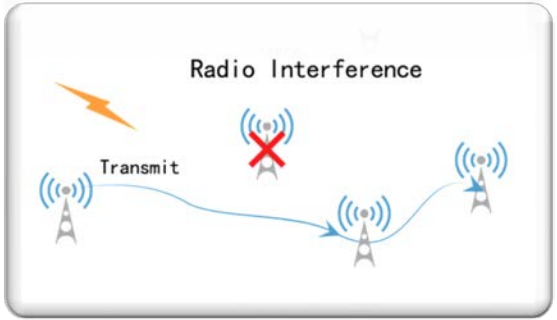
Multi-connectivity or topological redundancy has been defined in TR 38.974, to 1) enable robust operation (reliability) in the case of backhaul link blockage/failure, and 2) provide load balancing.

Since IAB nodes are usually not having towered and sectional antennas, link blockages and node overloading can be a **volatile** fact in IAB networks.

[1] Draft TR 38.874 v0.5, Study on Integrated Access and Backhaul.

L2 Cognitive Multi-hop Communications





Traditional multi-hop network

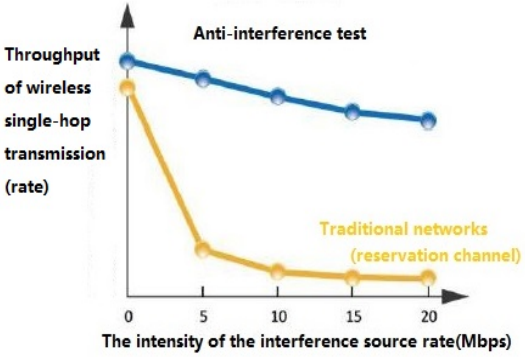
Traditional network layer routing requires predetermined routing and spectrum channel allocation in the medium access control. If there appears random interferences in the network, it will be retransmitted for many times on the predetermined link, introducing bottlenecks that can be accumulated over multiple wireless hops. The performance can then degrade exponentially.

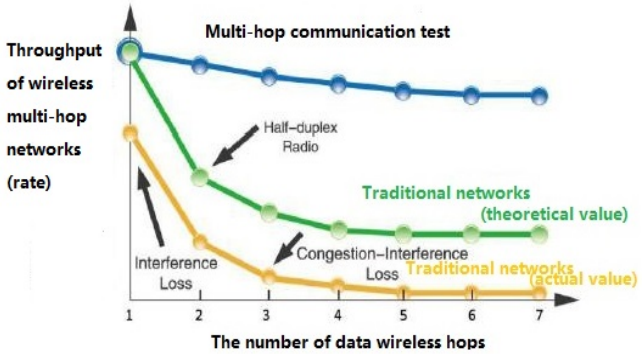
L2 cognitive multi-hop network

If there appears random interferences or link blockage in the network, every packet can be transmitted via opportunistic channels or opportunistic nodes, avoiding all the potential bottlenecks without predetermined routing path or spectrum allocation. Reliable end-to-end communications can be achieved, which does not degrade with the number of wireless hops.

[2] Liang Song, and Dimitrios Hatzinakos, “A Cross-layer Architecture of Wireless Sensor Networks for Target Tracking,” *IEEE/ACM Trans. on Networking,* vol. 15, no. 1, pp. 145-158, Feb. 2007.
[3] Liang Song, “Cognitive Networks: Standardizing the Large Scale Wireless Systems,” IEEE 2nd Workshop on Cognitive Radio Networks, Las Vegas NV, Jan. 2008.

Realizing scalable multi-hop in 5G IAB network





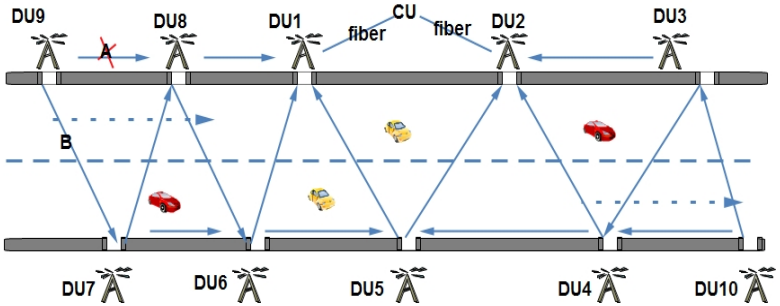
Compared to traditional networks, the cognitive multi-hop links can deal with wireless interference or link blockage over 1000 times faster in complex and dense networking environment, therefore it can maintain reliable communication rates and latency over multiple wireless hops.

	Routing	Spectrum	Throughput	Latency	Link Blockage	Overhead
New Multi-hop links	Link&PHY	Link&PHY	Stable	Linear	Robust	5-10%
Traditional	Network Layer	Link Layer	Degrading fast with hops	Large jitter	Prone and degrading	Up to 90%

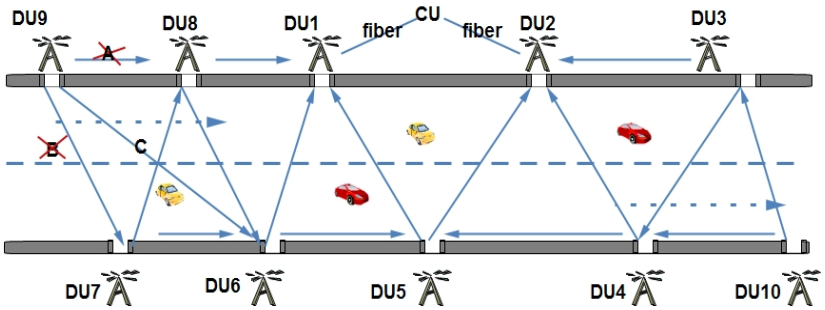
[4] Liang Song, “Wireless Mesh Infrastructure Supporting Broadband Internet with Multimedia Services,” IEEE International Conference on Circuits and Systems for Communications, Shanghai, China, 2008.

[5] Liang Song, and Dimitrios Hatzinakos, “Cognitive Networking of Large Scale Wireless Systems,” *International Journal of Communication Networks and Distributed Systems,* vol. 2, no. 4, pp. 452-475, 2009

Scenario 1: Backhaul Link Failure Handling



A typical IAB use case where multiple IAB nodes are deployed, e.g., on city street lights, every IAB node has at least two parents, so that a single backhaul link failure won't introduce any hard topology adaption. For example, if link A is blocked, DU9 can route through DU7 instead of DU8.

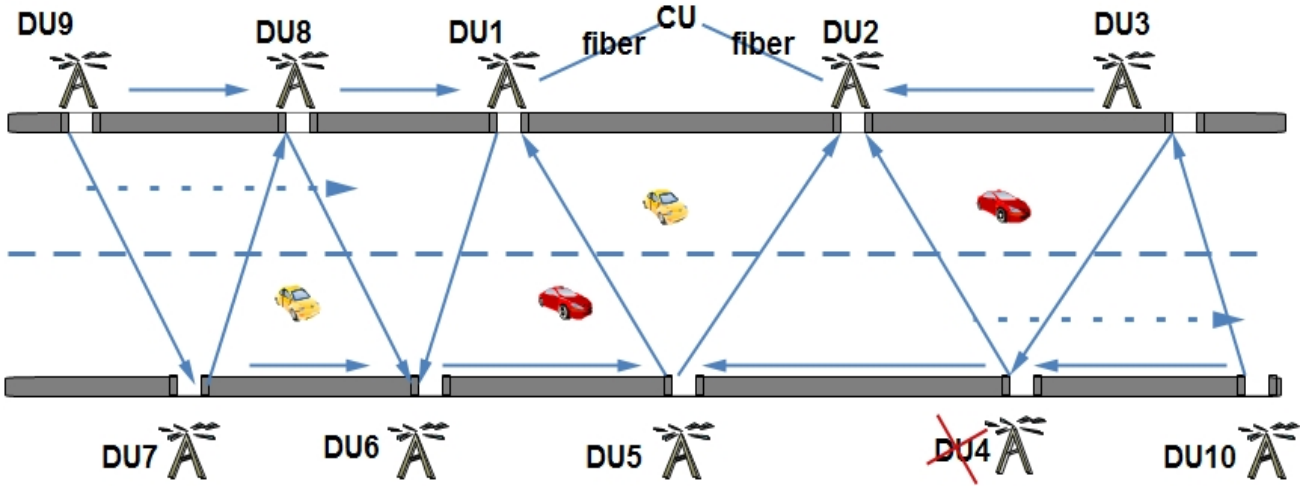


When DU9 has three parents, if any two links, e.g., A and B are both blocked, DU9 can route through DU6 instead of DU8 and DU7.

Definition 1: A *hard topology adaption* sets up new links to recover a partially disconnected IAB network – UE packet drops or latency will be introduced.

Definition 2: A *soft topology adaption* sets up new links to improve topological redundancy of a connected IAB network – no UE service interruption will be introduced.

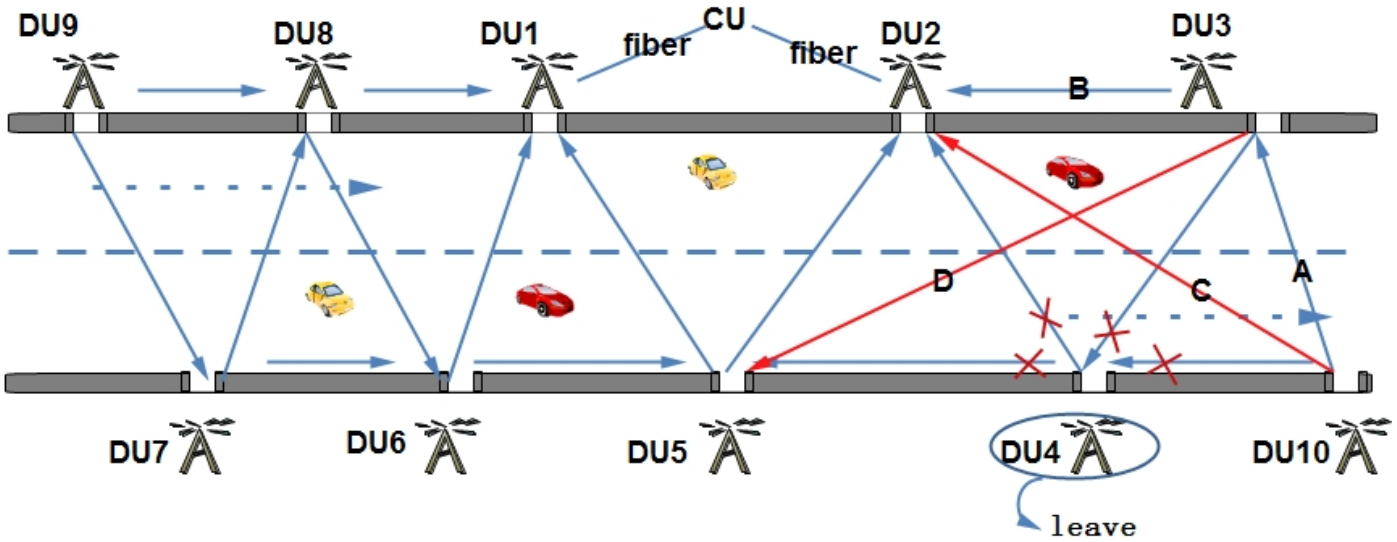
Scenario 2: Multi-connectivity for Load Balancing



When DU4 is overloaded, e.g., with an overflow of UL buffer, any further packets sent to DU4 will be subject to loss or long latency due to congestions.

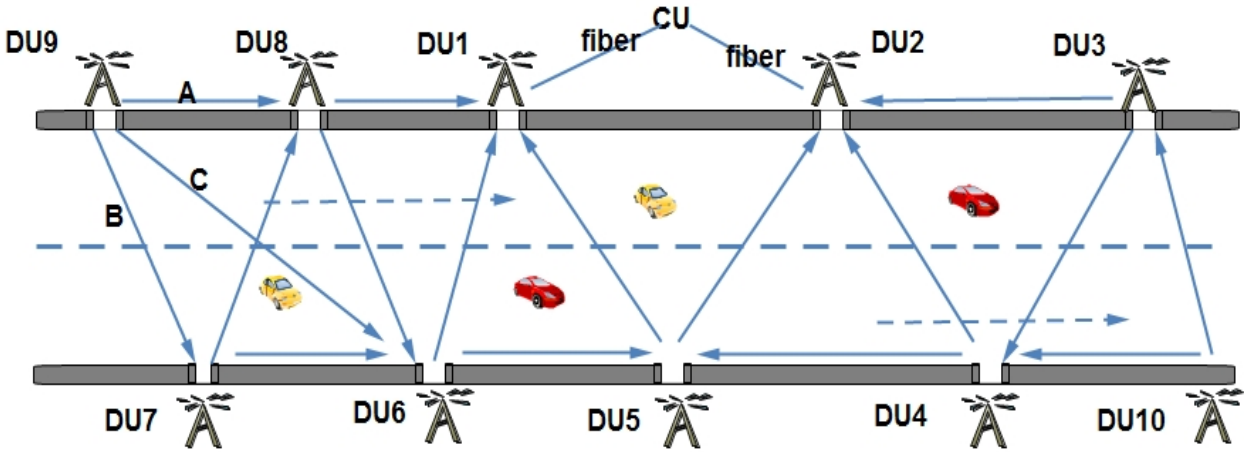
DU10 shall instantly route packets to DU3, and prevent sending any new packets to DU4 until the overloading is relieved. Similar mechanisms can be applied to DL as well. As congestions or overloading can occur frequently and swiftly in IAB, only relays with satisfied buffer load will be used.

Scenario 3: Soft Topology Adaption



It shows a typical scenario where an IAB node DU4 is subject to permanent failure and leaves the network. Under the original topology, DU3 and DU10 only have one parent, which introduces a risk of hard topology adaption if a further blockage of link A or link B occurs. In this case, a soft topology adaption is performed by the CU to set up new links C and D which recovers the dual-connectivity of DU3 and DU10.

Scenario 4: Cognitive Routing under Multi-connectivity



Definition 3: The cost of delivery (COD) between any two IAB nodes indicates a long-term average cost of sending a packet, between the two IAB nodes under current IAB network topology.

The COD in the left figure could be either in average hops or distance.

DU9 has three potential next relays in UL - parents, DU8, DU6, and DU7. If all the three relays have satisfied link quality and buffer load, DU6 shall be selected as the next hop relay since it is having closest distance to the destination CU. However, if link C is temporarily blocked or DU7 is overloaded, DU8 shall be selected instead.

Cognitive routing decides the next-hop relay by selecting the least cost of delivery to the destination node, under the instantaneous conditions of satisfied link quality and buffer load.

Summary

- Long-term soft topology adaption to maintain the muilt-connectivity redundancy.
- Short-term L2 cognitive routing to deliver the ultra reliable and low latency multi-hop IAB networking.
- Proposals are provided in R3-185402.

THANK YOU!

OMESH

2018.10