Performance improvement of TDMA-based wireless mesh networks

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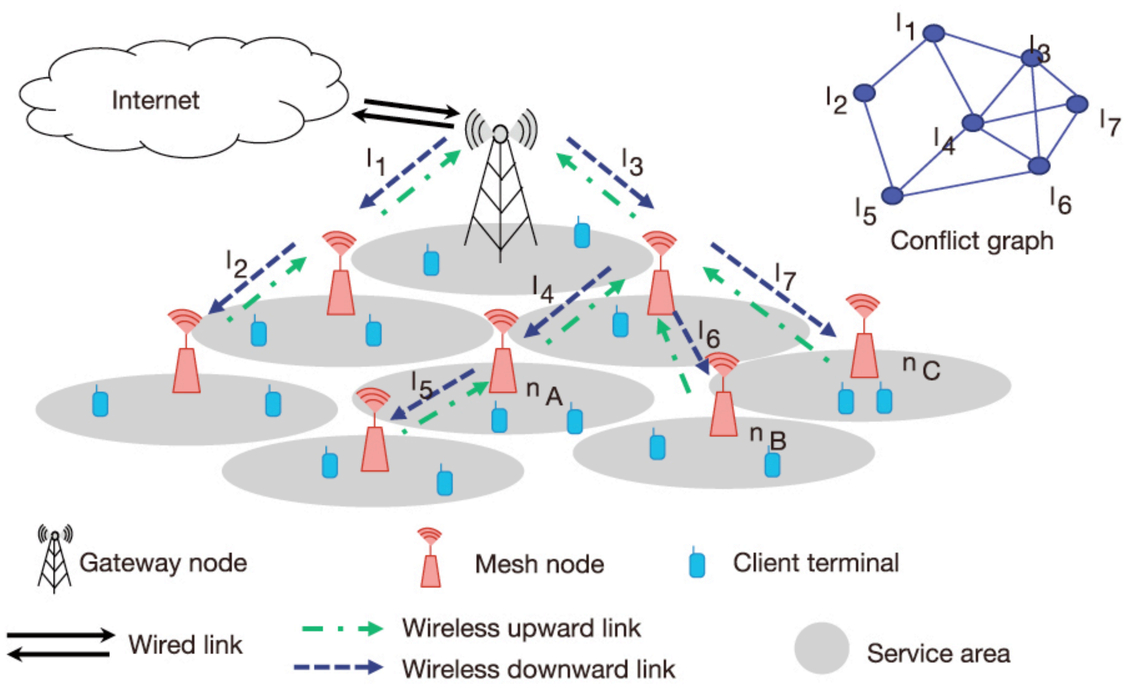
TDMA-based wireless mesh networks

Wireless mesh networks (WMNs), which are used for providing a wide-area wireless broadband access environment (e.g., IEEE 802.16j relay networks), have attracted much attention because of their expandability and cost efficiency. WMNs consist of a gateway node, which is connected to a wired network, and mesh nodes. A mesh node provides wireless broadband access service to client terminals within its service area. Mesh nodes are connected through a wireless link when they are within transmission range of each other.



When closely located links in a wireless network are used simultaneously, a receiver node cannot correctly receive radio signals from the corresponding sender node because of radio interference. In time division multiple access (TDMA) protocols, time is divided into frames, each frame consists of time slots of a constant duration, and different time slots are assigned to links that interfere with each other.

Our research group has proposed a variety of methods for improving the performance of TDMA-based WMNs:

- Topology construction methods for gateway load balancing
- Power control methods for improving spatial reuse
- Time slot assignment methods for reducing transmission latency [1]
- Methods for improving service area quality based on geometric algorithms [2]
- Node repositioning methods for reducing transmission latency

For more details on each method, please visit our group' s web site (http://www.ane.cmc.osaka-u.ac.jp/). We briefly introduce two of the methods in the following section.

Time slot assignment methods for reducing transmission latency [1]

TDMA protocols cause scheduling delays. A scheduling delay is the period of time between the arrival of a packet at a mesh node and the departure of the packet at the scheduled time slot for the mesh node. Therefore, in multi-hop WMNs, end-to-end transmission latency between a mesh node and a gateway node can be increased by accumulating the scheduling delay at each hop on the path between the client terminal and the gateway node.

We have proposed time slot assignment methods for reducing transmission latency in WMNs by extending the existing method [3], which aims at better network throughput and a small frame length. In our proposed methods, the set of interference relationships among links, i.e., a conflict graph, is first obtained. Then, the order of links for time slot assignment is determined. Finally, time slots are assigned to the links according to the determined order. Unlike in [3], our methods configure the order of time slot assignment by considering the hop count from the gateway node, and as a result, the transmission latency decreases without increasing the frame length. Our proposed methods also accommodate the weighted time slot assignment, which is consistent with IEEE 802.16j specifications.

Link	l_7	l_6	l_4	l_3	l_5	l_1	l_2
Link order	1	1	1	1	2	2	3
Assignment orders	1	2	3	4	5	6	7

Link	l_7	l_6	l_4	l_3	l_5	l_1	l_2
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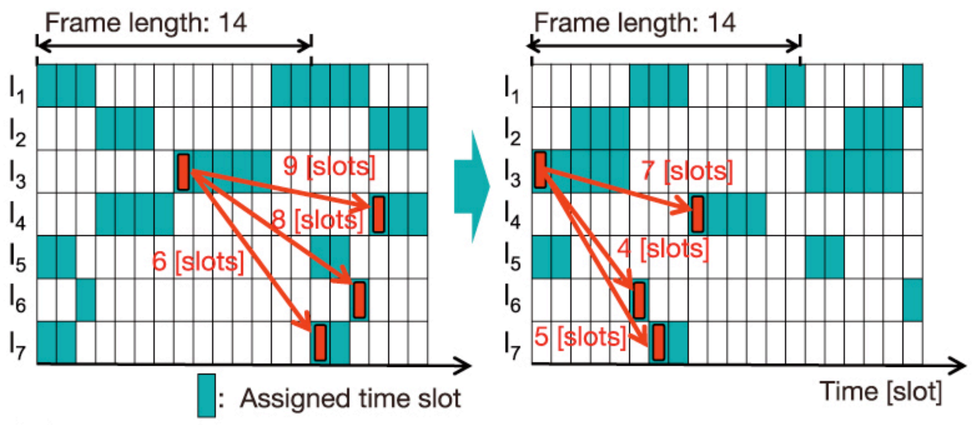
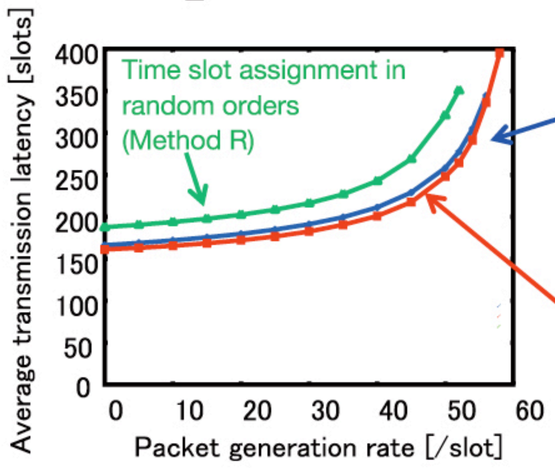




Proposal utilizing weighted time slot assignment
Compared with Method R, the transmission latency is decreased by up to 20%.

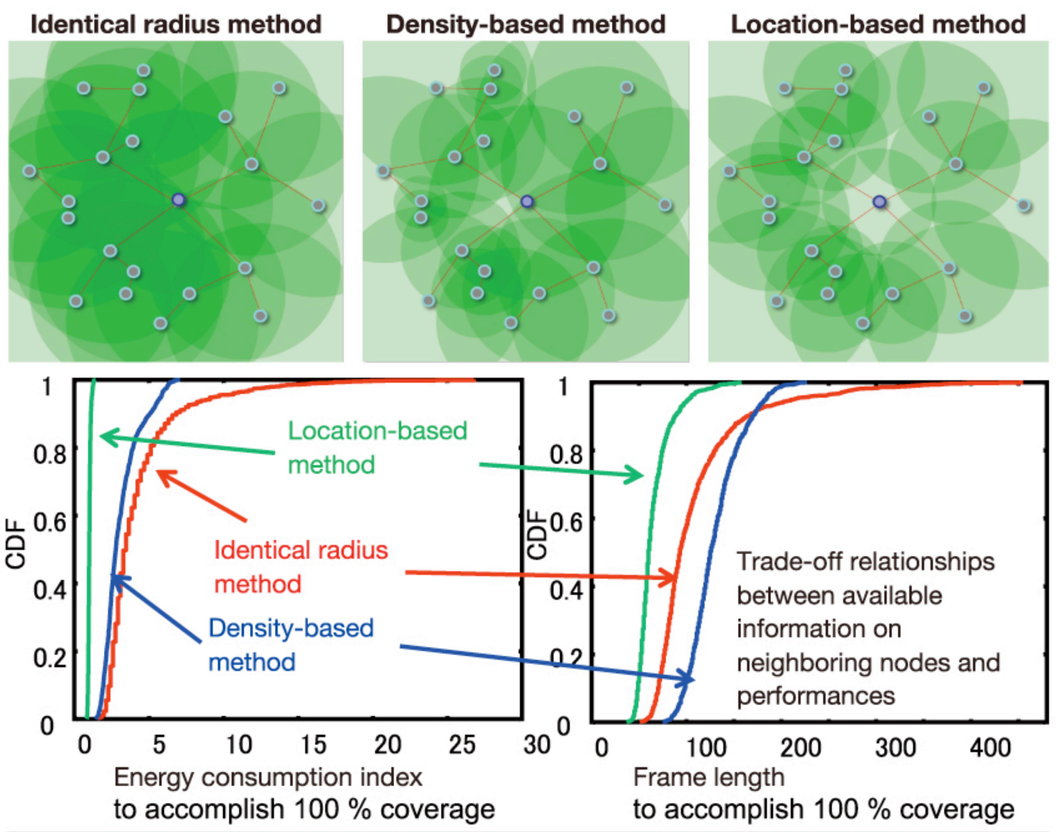
Proposal utilizing weighted time slot assignment and the refined time slot assignment orders
Compared with Method R, the transmission latency is decreased by up to 25%.

Methods for improving service area quality based on geometric algorithms [2]

The performance metrics of wireless mesh networks, such as communication quality and energy consumption, are significantly affected by service area size and its overlap degree. In order to adequately determine the service area size for each node, it is important to use the location information of neighboring nodes. However, due to the environments where the WMN is deployed, such information is not always available, or is only partially available.

We have proposed several methods for determining the service area size according to various kinds of available information on neighboring nodes:

- Identical radius method: All nodes use an identical service radius. This method is suitable for situations in which each node is unable to obtain information.
- Density-based method: Each node estimates the nearest neighbor' s distance and sets its service radius based on the estimation results. This method is for situations in which each node can obtain the number of its neighboring nodes.
- Location-based method: Each node sets its service radius to cover its Voronoi area. This method is for situations in which each node can obtain precise location information for neighboring nodes.



[1] R. Ishii et al., "Time slot assignment algorithms in IEEE 802.16 multi-hop relay networks," Proc. ICNS 2010.
[2] S. Takemori et al., "Service area deployment of IEEE 802.16j wireless relay networks: service area coverage, energy consumption, and resource utilization efficiency," Int. J. Advances in Internet Tech. 3(1-2):43-52 (2010)
[3] W. Wang et al., "Efficient interference-aware TDMA link scheduling for static wireless networks," Proc. ACM MobiCom 2006.

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