Distributed Frequency Synchronization for OFDMA-based Wireless Mesh Networks



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- Synchronization Issue in Wireless Mesh Network
 - In wireless mesh network, each distributed node locally synchronizes with its neighbor nodes to communicate with them.



- Synchronization Issue in Wireless Mesh Network
 - Distributed nodes carry out resource allocation and scheduling to avoid multiple pair interference.



- Synchronization Issue in Wireless Mesh Network
 - Even if perfect resource allocation and scheduling scenario is assumed, multiple pair interference exists due to synchronization problem.



Synchronization Issue in Wireless Mesh Network



- Synchronization Issue in Wireless Mesh Network
 - In OFDM systems, there exist three different problems related to synchronization.



- Sponsor-based Frequency Synchronization (SFS)
 - Each node synchronizes with only its sponsor node [1].



[1] I. Akyildiz and X. Wang, Wireless Mesh Networks. John Wiley Publishing Company, 2009.

- Consensus-based Frequency Synchronization (CFS)
 - Each node adjusts its carrier frequency to the average value [2],[3].



[2] M. K. Maggs, S. G. O'Keefe, and D. V. Thiel, "Consensus clock synchronization for wireless sensor networks," IEEE Sensors Journal, vol. 12, no. 6, pp. 2269-2277, June, 2012.
[3] Jung-Hyun Kim, Jihyung Kim, Kwangjae Lim, and Dong Seung Kwon, "Distributed Frequency Synchronization for Global Synchronization in Wireless Mesh Networks," ICNWC, Lucerne, Switzerland, Oct. 15-16, 2012.

- Distributed Frequency Synchronization (DFS) [3]
 - A global frequency synchronization method for wireless mesh network

[3] Jung-Hyun Kim, Jihyung Kim, Kwangjae Lim, and Dong Seung Kwon, "Distributed Frequency Synchronization for Global Synchronization in Wireless Mesh Networks," *ICNWC*, Lucerne, Switzerland, Oct. 15-16, 2012.



- Modified Distributed Frequency Synchronization (mDFS)
 - Modified version of DFS dealing with some practical issues and bias problem

Core algorithms of DFS

Repetitive estimation, averaging offsets, sharing estimates



Repetitive Estimation

• Each node receives a preamble signal several times from a neighbor node to obtain diversity gain.



Sharing Estimates

▶ To increase estimation accuracy more, we use sharing message.



Averaging Offsets

• Each node estimates frequency offsets with neighbor nodes and then calculates the average value of these offsets.





With and without bias compensation



Why we need the bias compensation?

In group separation and merge scenario, strong interference can occur temporally.



How to compensate the bias?

• Each node compensates its carrier frequency using both of own variation and neighbor's variation.



[4] Y. Chen, R. Tron, A. Terzis, and R. Vidal, "Corrective consensus: Converging to the exact average," in Proc. IEEE Conf. Decision Control, Dec. 2010, pp. 1221–1228.

OFDM parameters	IEEE 802.16m [5]
Channel model	RMa, LoS model [6]
Network topology	21 randomly distributed nodes in 40 <i>km ×</i> 40 <i>km simulation plain</i> One hop distance is 10 <i>km</i> (<i>SNR</i> = 8.47 <i>dB</i>)
velocity	120 <i>km/h</i>
Synchronization threshold ($m{arepsilon}_{th}$)	1% subcarrier spacing
Number of repetitive estimation	3
Period of bias compensation	every 5 DFS updates

Synchronization success criteria



$$\max(\boldsymbol{\varepsilon}_i) \leq \boldsymbol{\varepsilon}_{th}, \ (\boldsymbol{i} = l, \cdots, N)$$

 ε_i : frequency offset between a target n and its ith neighbor node

[5] IEEE 802.16m, Part 16: Air Interface for Broadband Wireless Access Systems: Advanced Air Interface, May, 2011. [6] Recommendation ITU-R M.1225, "Guidelines for the evaluation of radio transmission technologies for IMT-2000," 1997.

Simulation Results



 I. Akyildiz and X. Wang, Wireless Mesh Networks. John Wiley Publishing Company, 2009.
 M. K. Maggs, S. G. O'Keefe, and D. V. Thiel, "Consensus clock synchronization for wireless sensor networks," IEEE Sensors Journal, vol. 12, no. 6, pp. 2269-2277, June, 2012.
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Conclusions

The proposed *mDFS*



- Reduces memory size by replacing estimated average offset instead of storing all repetitive estimates
- Provides offset calculation method for reception failure of preamble signal and/or sharing message
- Defines update period and provide an example of it without loss of both convergence speed and estimation performance
- Compensates the bias of convergence value of carrier frequency using corrective consensus algorithm