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

Submission Title: [Distributed TDMA Scheduling for SOP]
Date Submitted: [4th May, 2009]
Source: [Seung-Hoon Park / Jeongsik In / Sridhar Rajagopal / Eui-Jik Kim / Ranjeet Kumar Patro / Noh-Gyoung Kang / Chihong Cho / Giriraj Goyal / Ashutosh Bhatia / Thenmozhi Arunan / Kiran Bynam / Arun Naniyat / Farooq Khan / YongSuk Park / Eun-Tae Won] Company [Samsung Electronics Co. Ltd.]
Address [416, Maetan-3dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, 443-742, Korea]
Voice: [+82-31-279-4579], FAX: [+82-31-279-5130],
E-Mail: [shannon.park@samsung.com]

Re: [Responses to Call for Intent in Wireless Body Area Networks]

Abstract: [This document proposes the method to schedule time resource for SOP of BAN]

Purpose: [To propose scheduling algorithm for SOP to support BAN high data rate applications]

Distributed TDMA Scheduling for SOP

Samsung Electronics

Motivation

- High data rate service [1]
  - Streaming service with see-through goggle
  - Video recording & storage
- BAN piconet environment
  - Frequent encounter with other piconets
- Time resource sharing is required
  - QoS requirement
    - Collision affects packet error rate
  - UWB band opened globally is narrow [2]
    - A few number of frequency bands

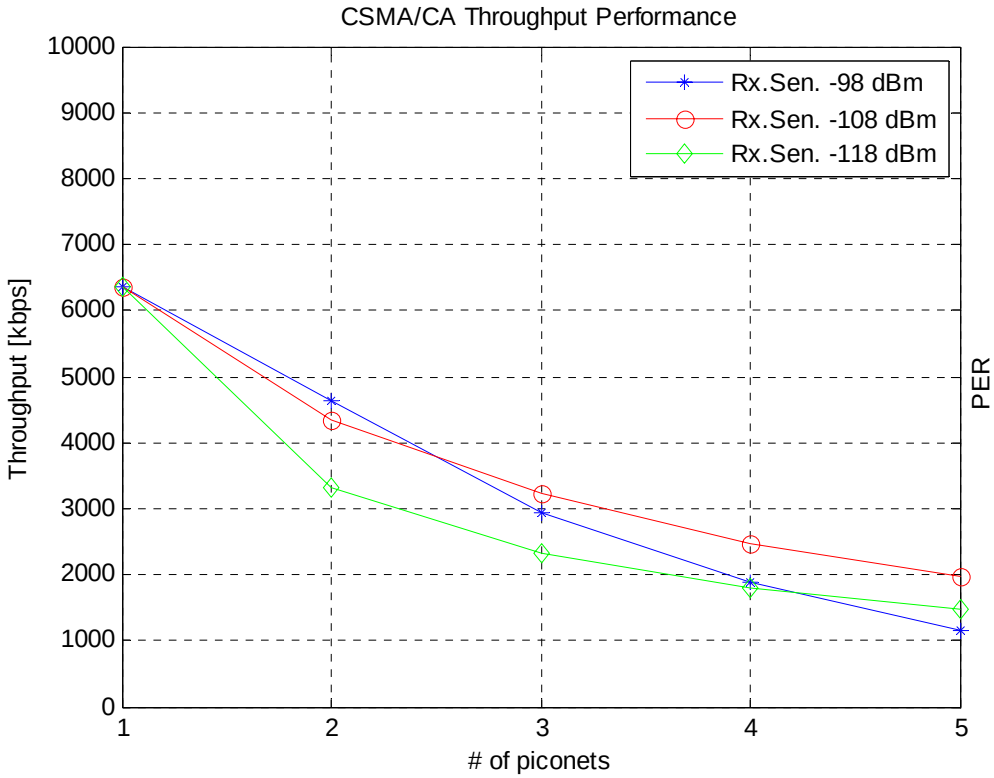
Possible Solutions for SOP

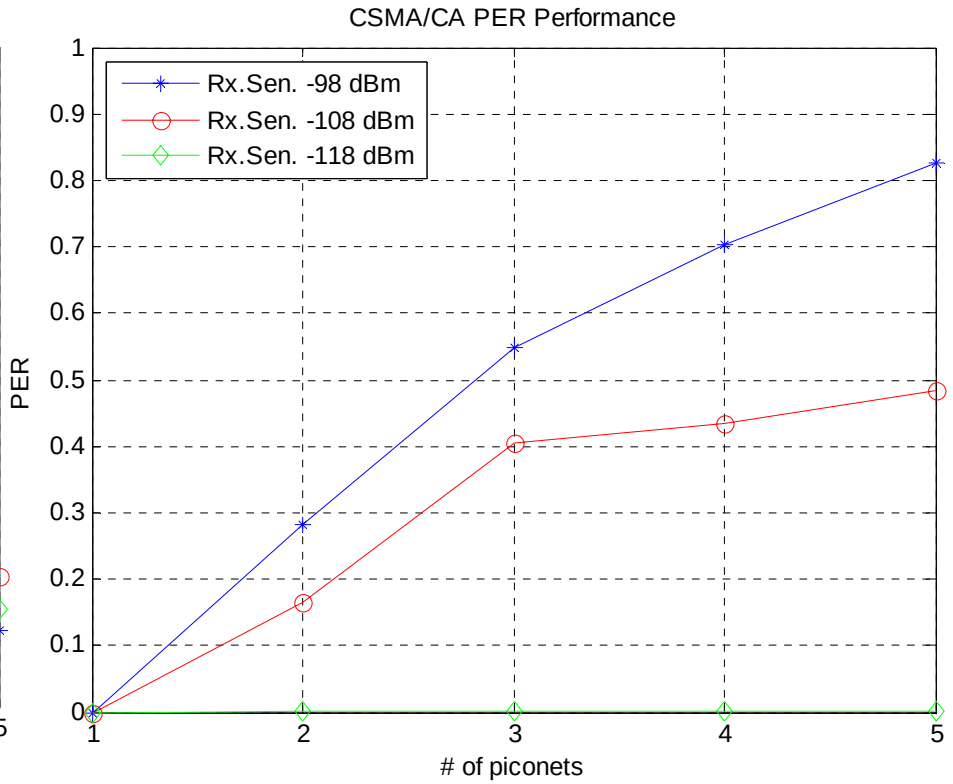
- FDMA
  - How to allocate bands ?
    - Band management makes the system complex
- Direct spread spectrum, frequency hopping, or time hopping
  - Only low data rate can be supported
- Contention-based access (CSMA)
  - Not delay bounded
  - Hidden node
  - Channel sensing is not easy at UWB, implant (MICS) or body shadowing condition [3]
- Contention free allocation (TDMA, polling)
  - Bandwidth efficient with dynamic slot allocation

Inter-piconet Collision

- Collision types
  - Piconet A ↔ Piconet B
  - TDMA ↔ TDMA
    - Can not avoid collision without any control
  - TDMA ↔ CSMA
    - Piconet B can reduce collision ratio by channel sensing
  - CSMA ↔ CSMA
    - CSMA without slot synchronization
- Low receiver sensitivity is required for CSMA

CSMA/CA Performance



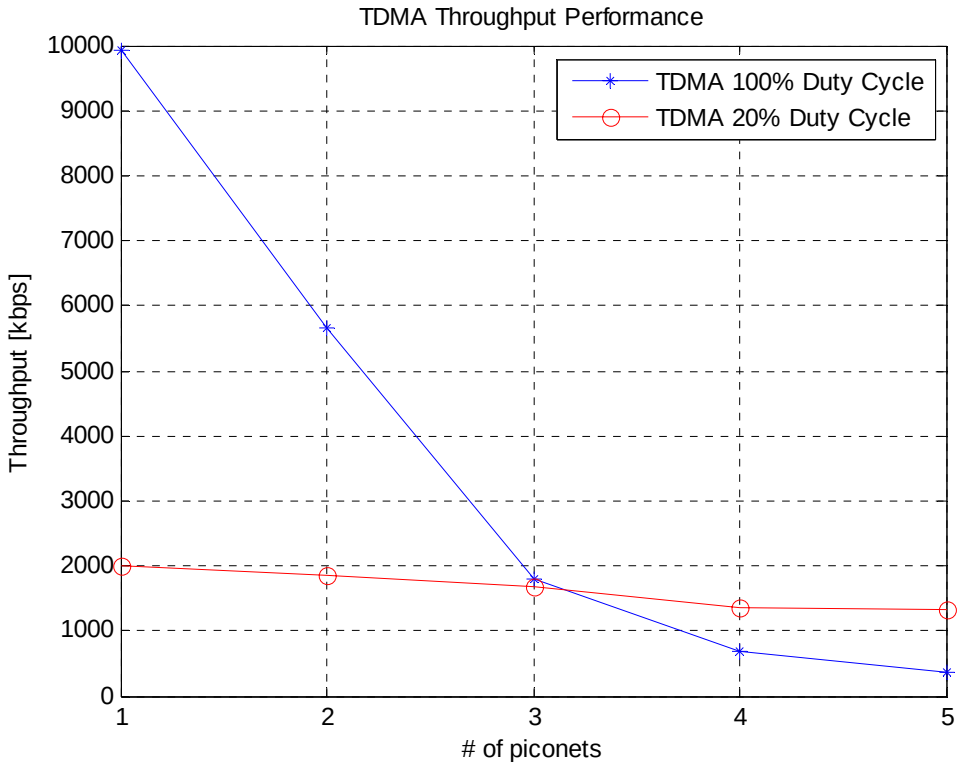


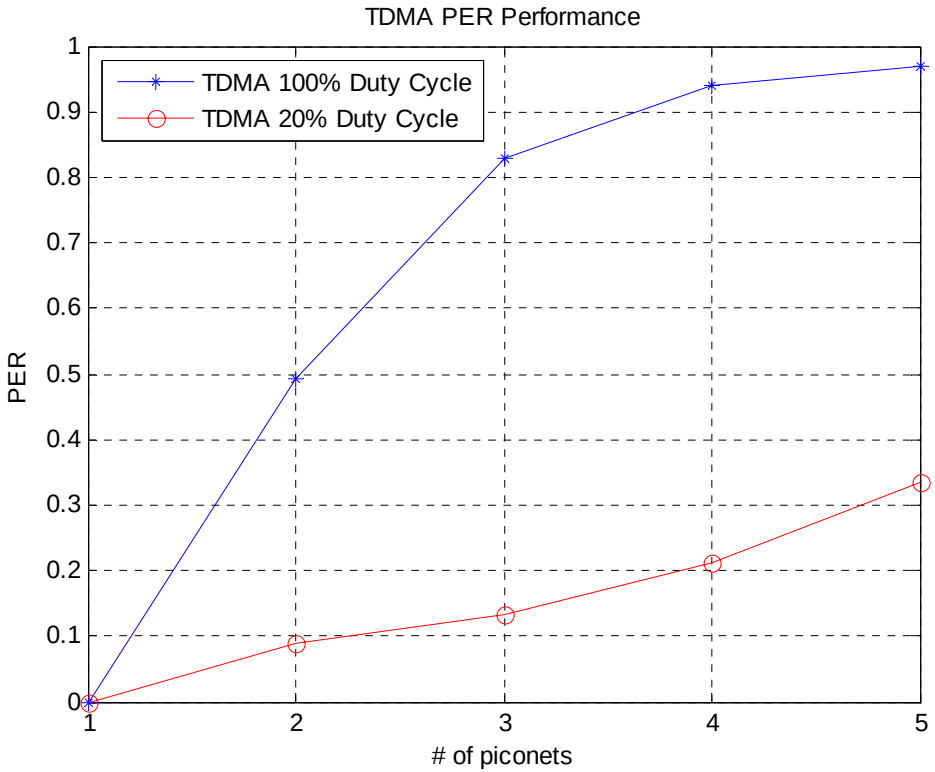
* Rx. Sensitivity of 802.15.4a UWB PHY is -85dBm (for 1Mbps) or -91dBm (for 250kbps).

TDMA

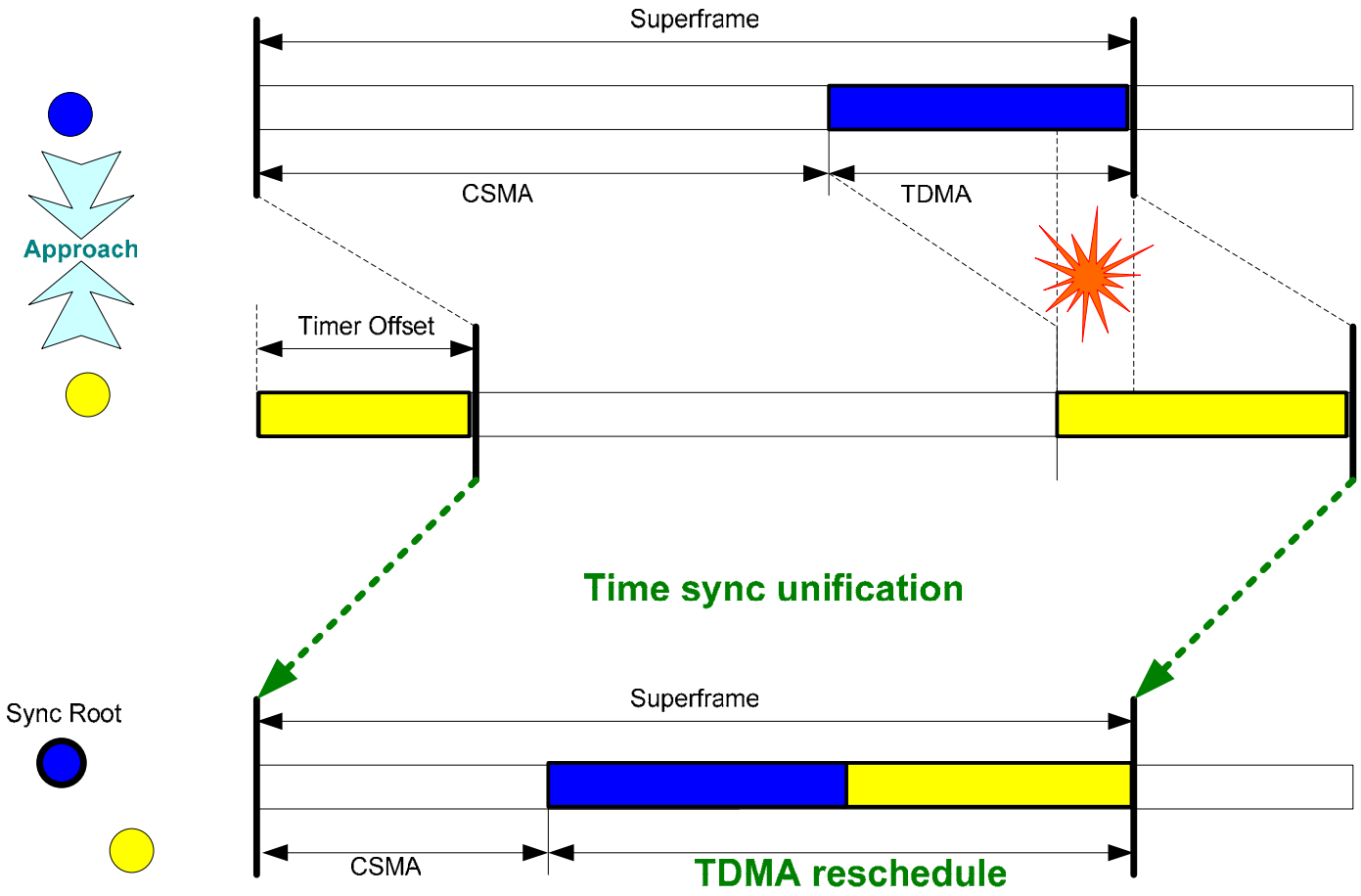
- Contention free allocation
- Pros
  - Guaranteed QoS
  - High channel efficiency
  - Very low power consumption
- Cons
  - Inter-piconet collision induces much performance degradation
- How to sync and schedule ?

TDMA Performance

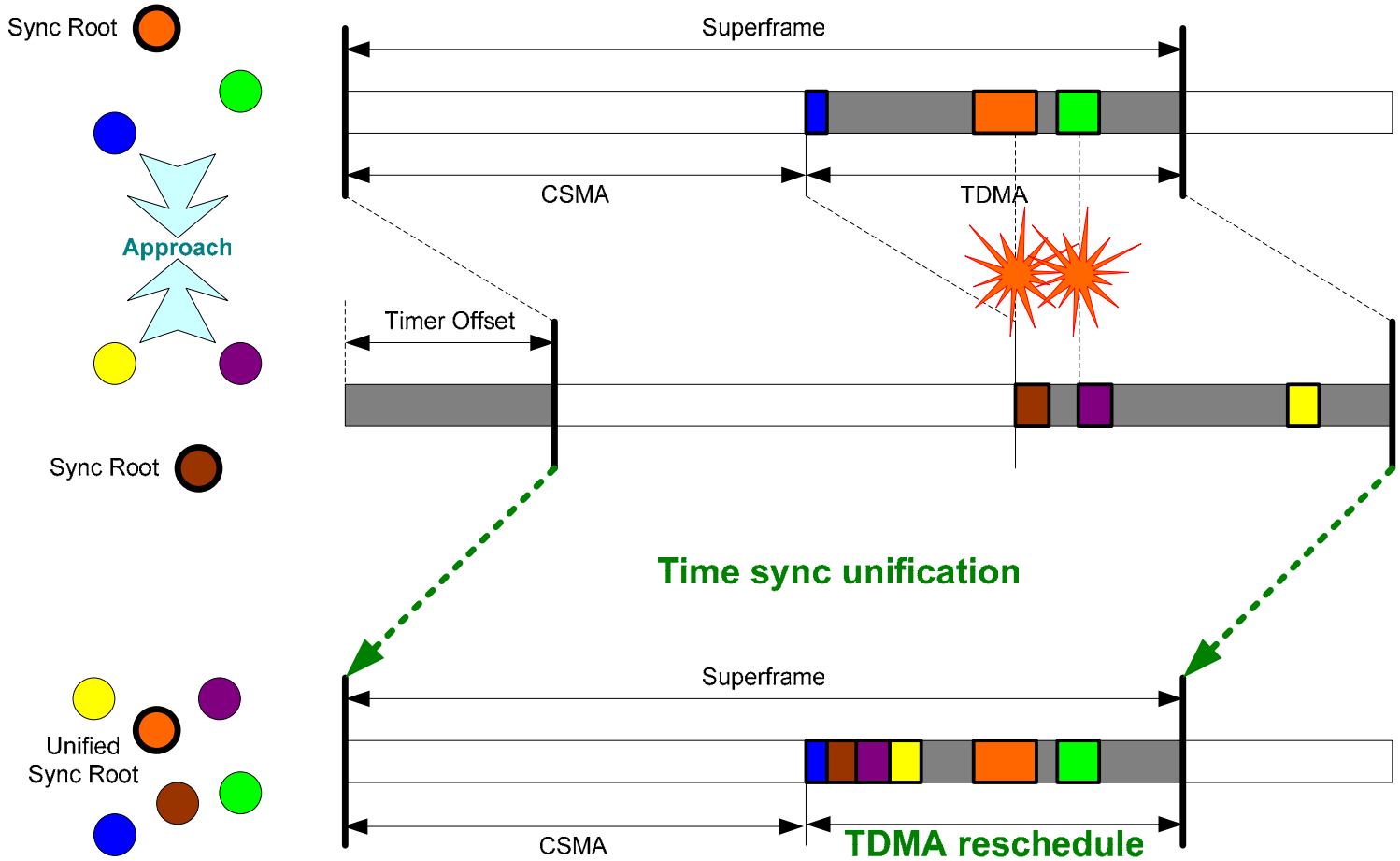




Centralized Piconet Merging



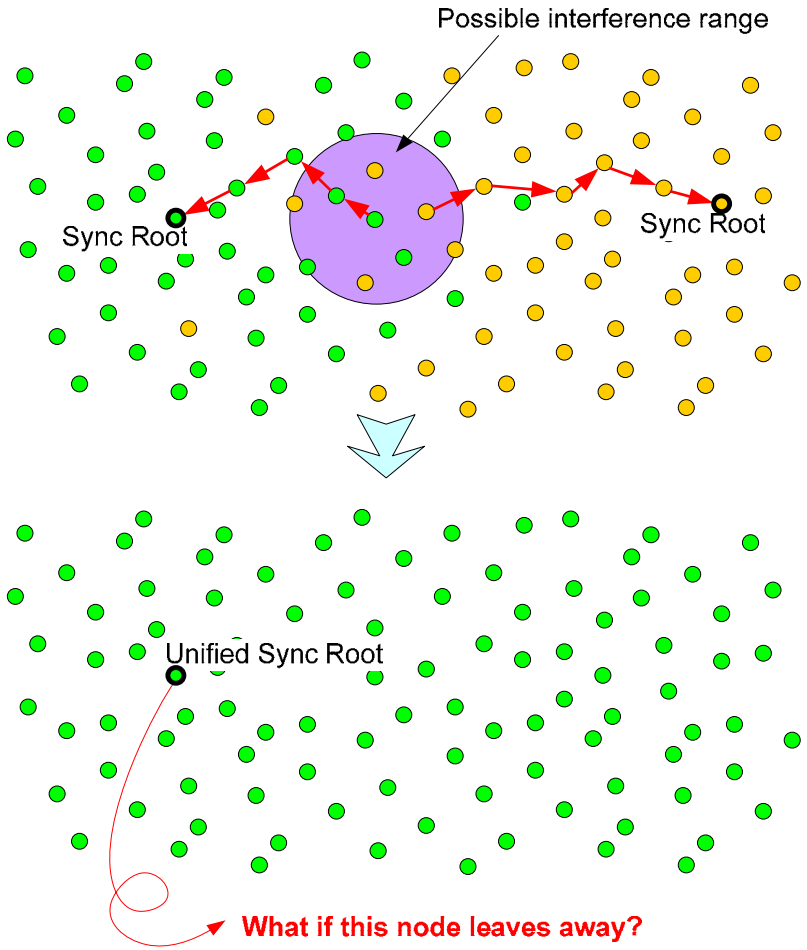
Centralized Piconet Merging



Problems of Centralized Piconet Merging

- BAN Piconet
  - Piconet is moving
  - High density in the specific location
- Fine synchronization is very difficult
- Centralized approach is apt to failed
  - Sync root node is changed frequently
  - Low scalability
    - Long latency
    - Large signal overhead

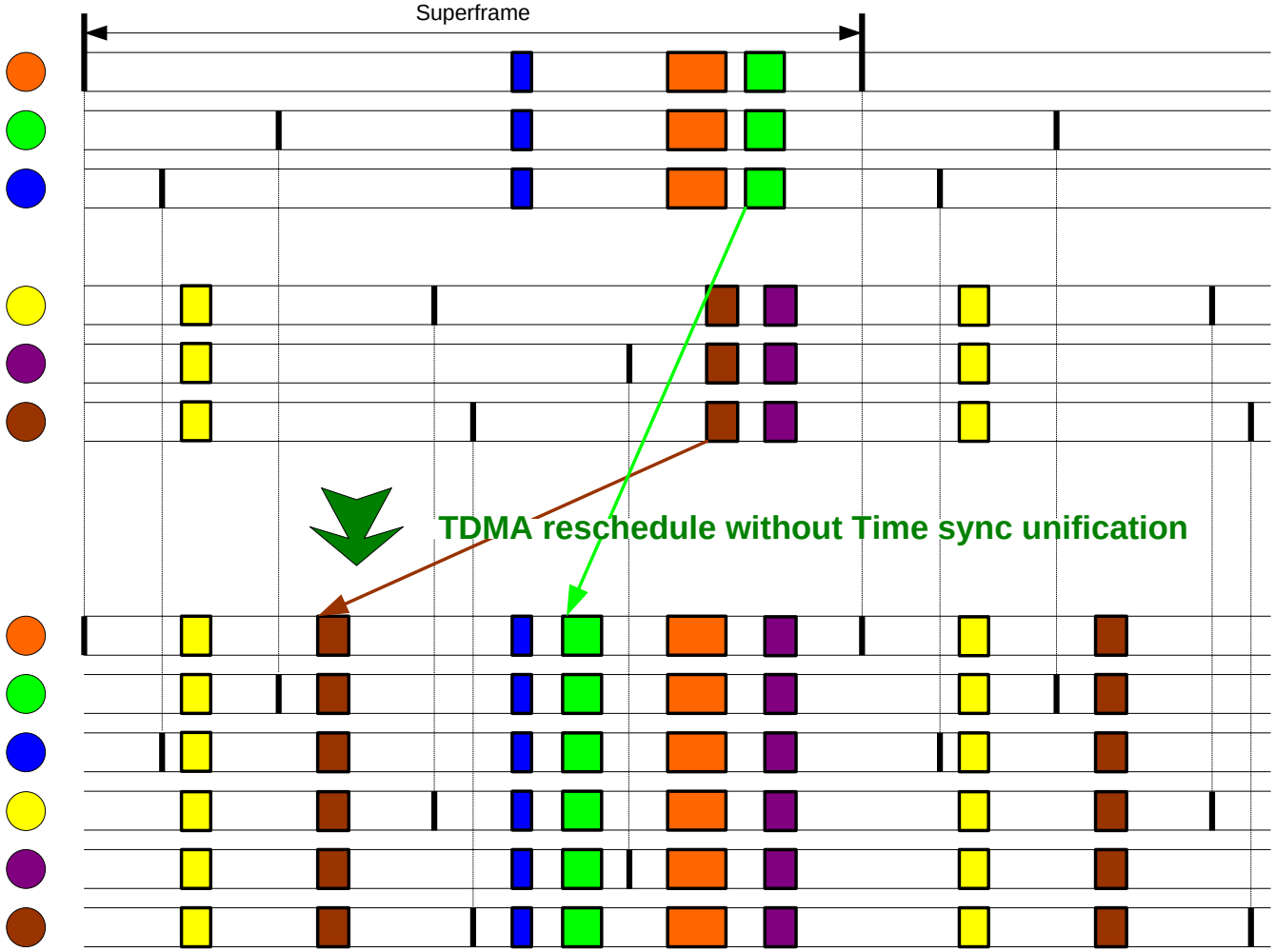
Problems of Centralized Piconet Merging



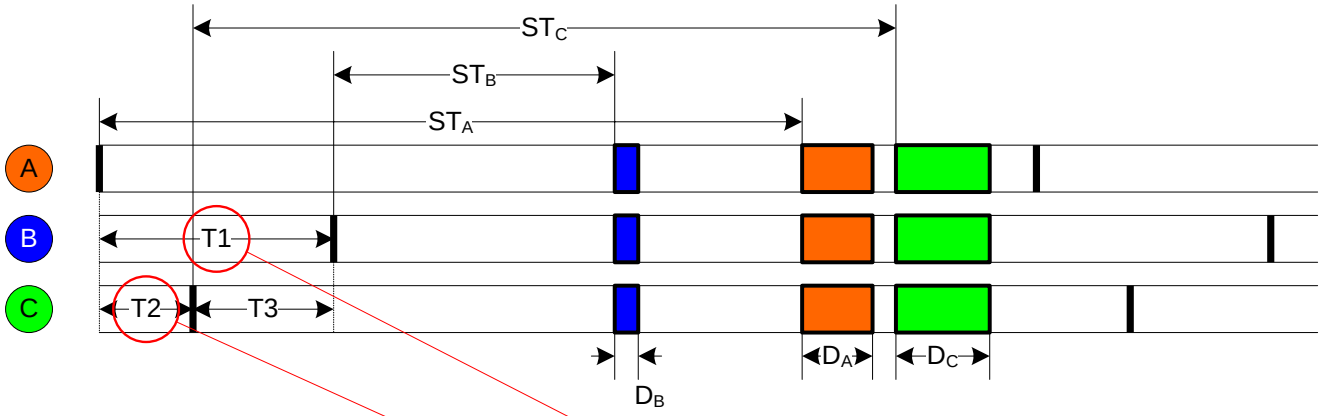
Resolving Approach

- Distributed scheduling
  - Only local consensus is required
    - No sync root
  - Exchanging time information between neighboring piconet coordinators
- Loose synchronization
  - Just avoiding slot allocation over the whole TDMA duration allocated by neighboring piconets
  - No need to fitting at slot level

Distributed TDMA Scheduling



Local Time Offset Exchange



TDMA Schedule Advertisement Message

Addr	# hop	Slot Start	Slot Dur	Seqno

TDMA schedule Table A

Addr	# hop	Offset	Slot Start	Slot Dur	Seqno
A	0	0	ST_A	D_A	SN_A
B	1	T1	ST_B + T1	D_B	SN_B
C	1	T2	ST_C + T2	D_C	SN_C

TDMA schedule Table B

Addr	# hop	Offset	Slot Start	Slot Dur	Seqno
A	1	− T1	ST_A − T1	D_A	SN_A
B	0	0	ST_B	D_B	SN_B
C	1	− T3	ST_C − T3	D_C	SN_C

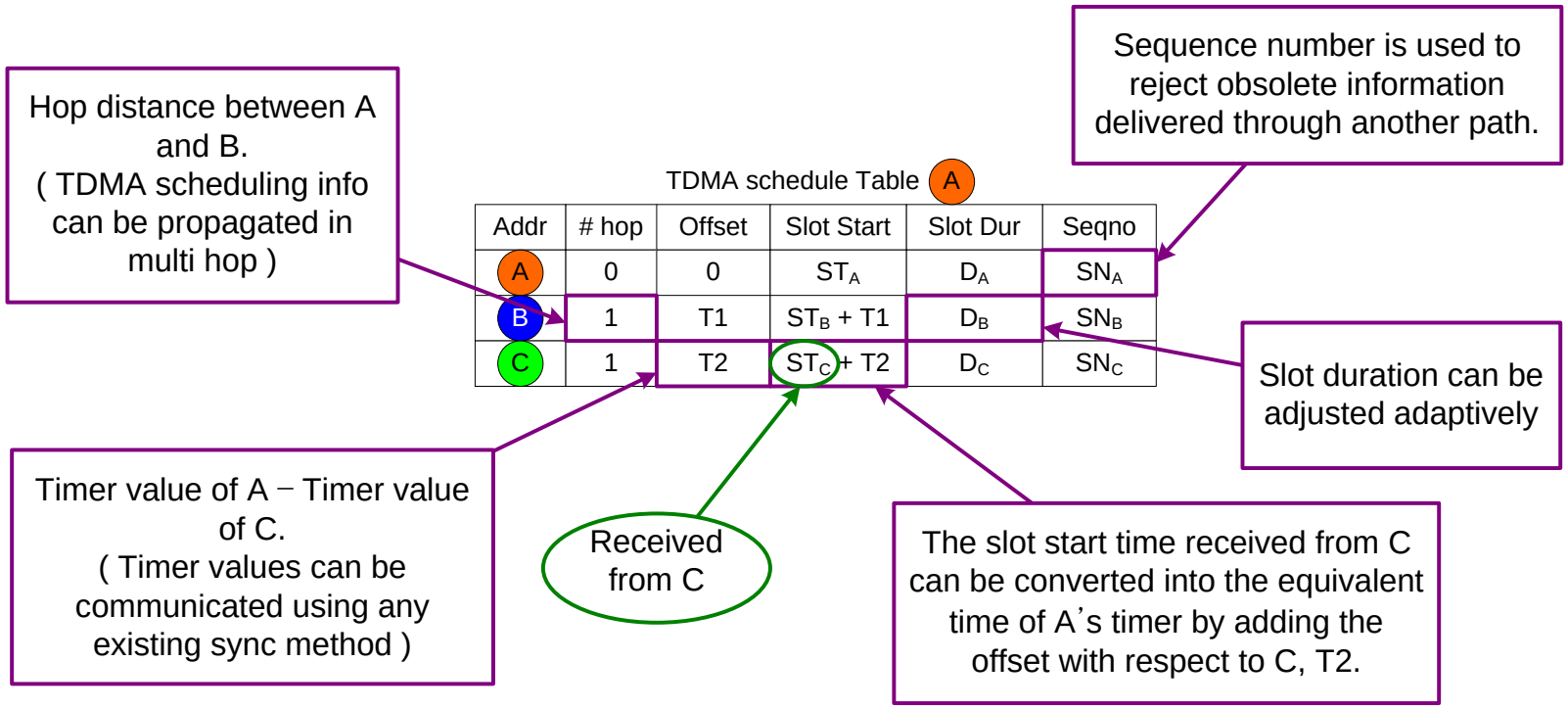
TDMA schedule Table C

Addr	# hop	Offset	Slot Start	Slot Dur	Seqno
A	1	− T2	ST_A − T2	D_A	SN_A
B	1	T3	ST_B + T3	D_B	SN_B
C	0	0	ST_C	D_C	SN_C

Offset Calculation

- Existing synchronization method
  - IEEE 802.11
    - Time stamping
  - IEEE 802.15.4
    - Beacon Tx. time control
- Any method can be used

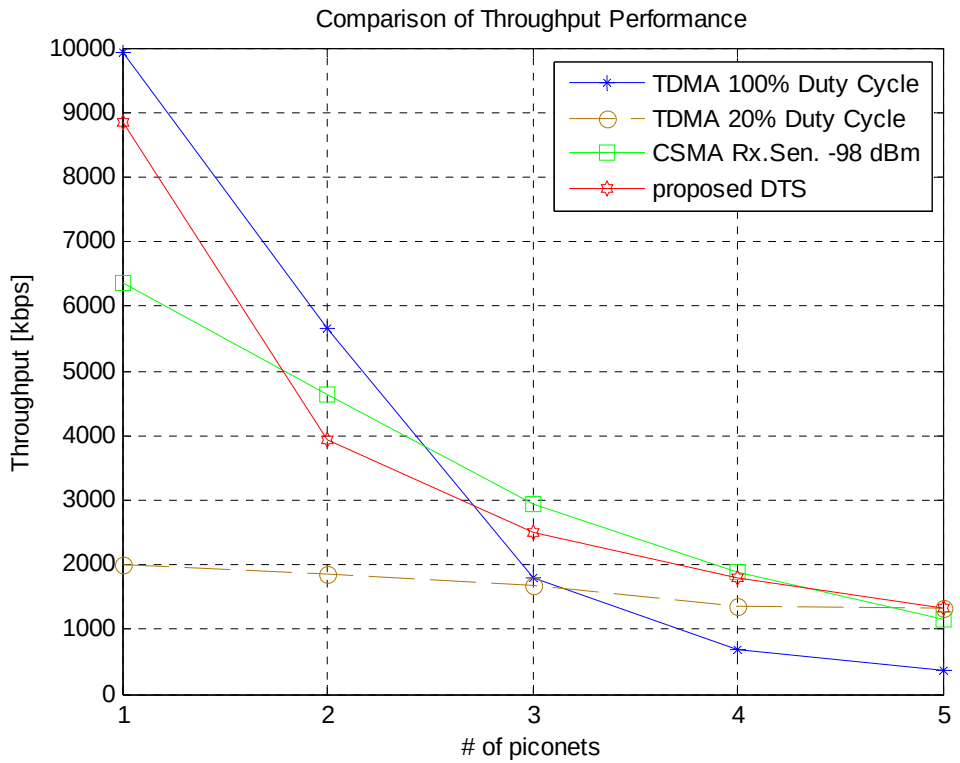
TDMA Schedule Table Calculation

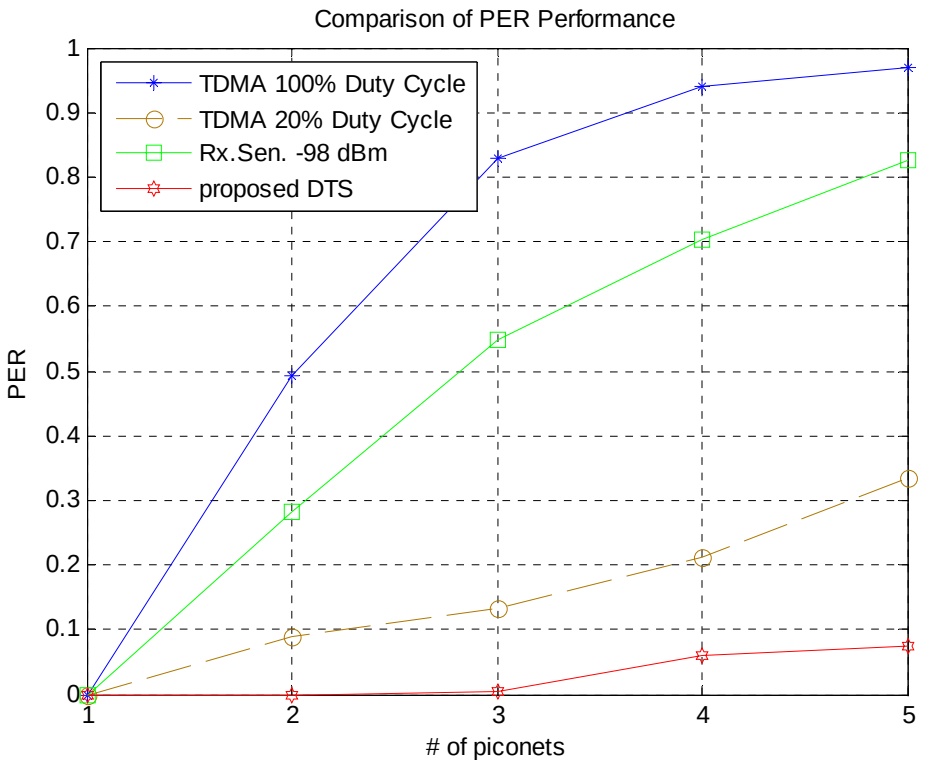


Simulation Setup

- 10Mbps downlink system
- Slot duration : 204.8 usec for 256 octet
- # of nodes in a piconet : 8
- randomly distributed 1~5 piconets in 6x6 m^2 area
- Traffic type : full queue traffic
- CSMA/CA parameters
  - CCA threshold : 10 dB
  - Rx. Sensitivity : -98 dBm
- Time information broadcasting
  - Sent at beacon time with robust coding

Simulation Results





Conclusion

- TDMA (contention free allocation)
  - Better goodput
  - Dynamic bandwidth allocation possible
  - Delay bounded
  - Mixable with other types of channel access mechanisms
    - CSMA, low duty cycle overlapping, or etc
- Distributed TDMA scheduling
  - Support dynamically changing multiple piconets

Welcome Merger

- Super-frame
  - CFP (Contention Free Period)
  - CAP (Contention Access Period)
- Partial proposal
  - Only SOP & QoS criteria is covered
  - Other companies are invited for collaboration

References

- [1] *"802.15.6 Call for Applications - Response Summary"*, 15-08-0407-05-0006-tg6-applications-summary.doc
- [2] "*IEEE standard for information technology - telecommunications and information exchange between systems - local and metropolitan area networks - specific requirement part 15.4: Wireless medium access control (MAC) and physical layer (PHY) specifications for low-rate wireless personal area networks (WPANs),*" IEEE Std 802.15.4a-2007 (Amendment to IEEE Std 802.15.4-2006), pp. 1–203, 2007.
- [3] "*BAN superframe for TG6*", 15-09-0162-00-0006-nict-mac-proposal-part-1-ban-superframe-for-medical-and-non-medical-applications.pdf

Thank You!

Q&A