

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

**Submission Title:** [Distributed TDMA Scheduling for SOP]

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**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]

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# Distributed TDMA Scheduling for SOP

# 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

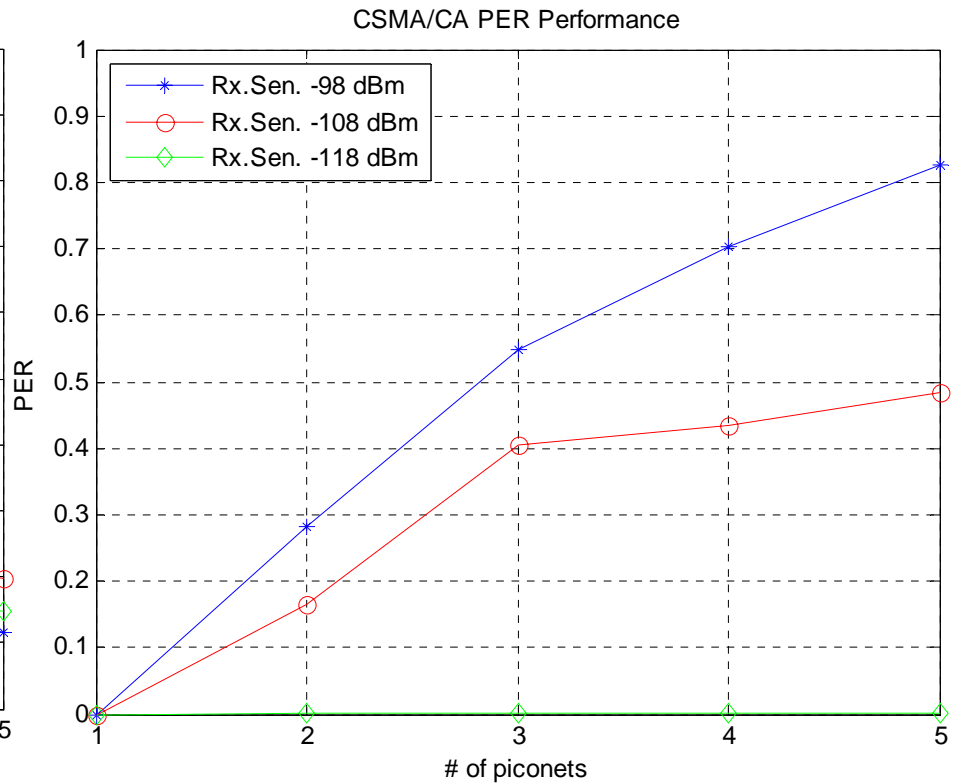
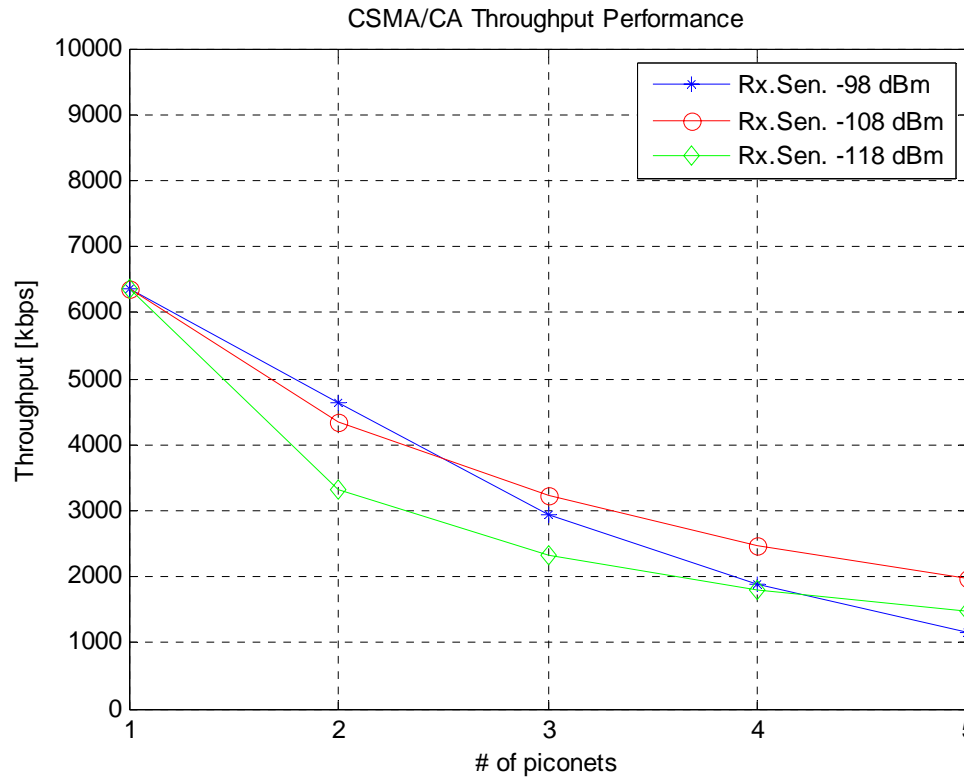
# Possible Solutions for SOP

- FDMA
  - How to allocate bands ?
    - Frequent change of band 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
- Contention free allocation (TDMA, polling)
  - Bandwidth efficient with dynamic slot allocation

# Inter-piconet Collision

- Collision types
  - Piconet A  $\leftrightarrow$  Piconet B
  - TDMA  $\leftrightarrow$  TDMA
    - Can not avoid collision without any control
  - TDMA  $\leftrightarrow$  CSMA
    - Piconet B can reduce collision ratio by channel sensing
    - low receiver sensitivity is required
  - CSMA  $\leftrightarrow$  CSMA
    - Same as the condition of CSMA in single piconet

# CSMA/CA Performance

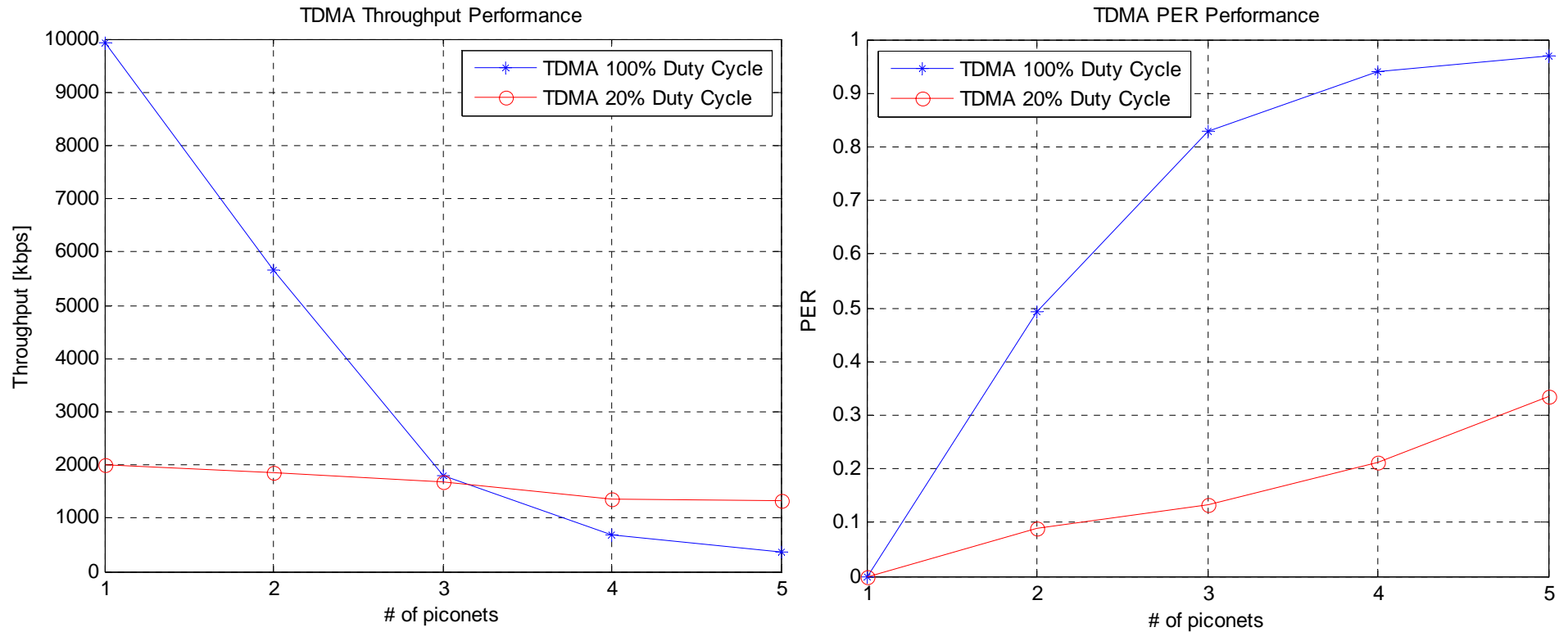


\* Rx. Sensitivity of 802.15.4a UWB PHY is 85dBm (for 1Mbps) or 91dBm (for 250kbps).

# TDMA

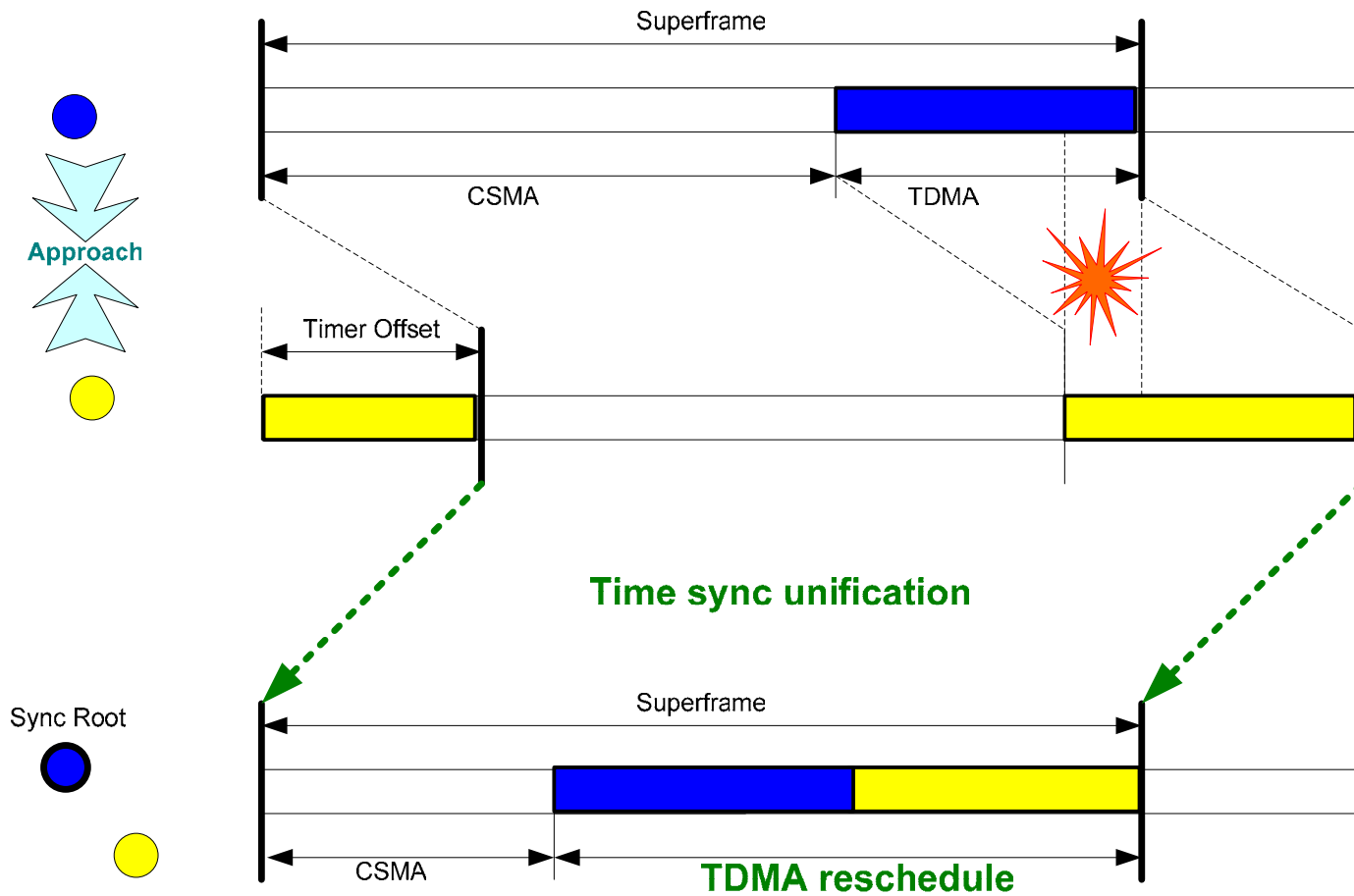
- Contention free allocation
- Pros
  - Guaranteed QoS
  - High channel efficiency
  - Very low power consumption
- Cons
  - Inter-piconet collision induces much performance degradation
- How to sync and schedule ?

# TDMA Performance

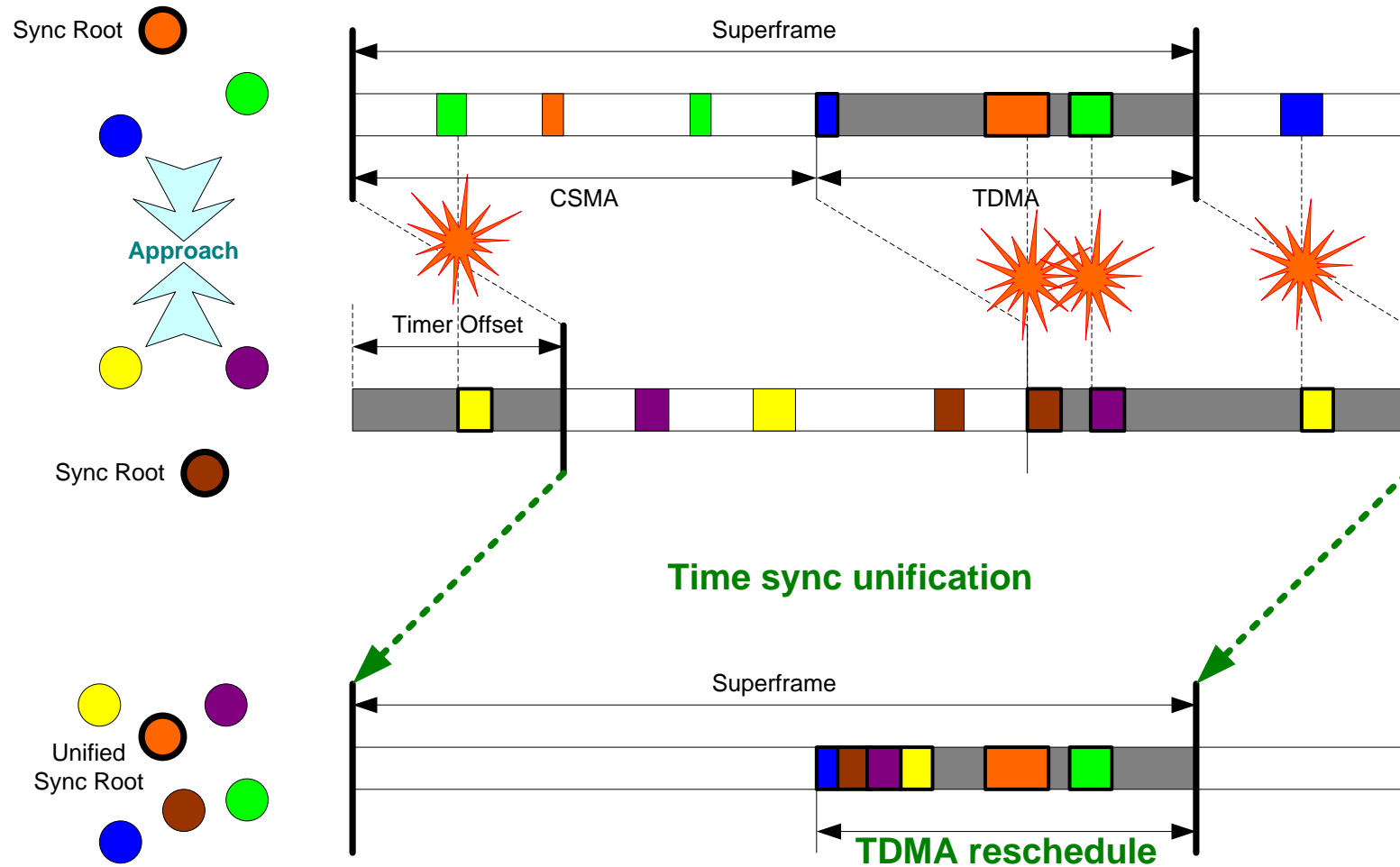




# Centralized Piconet Merging



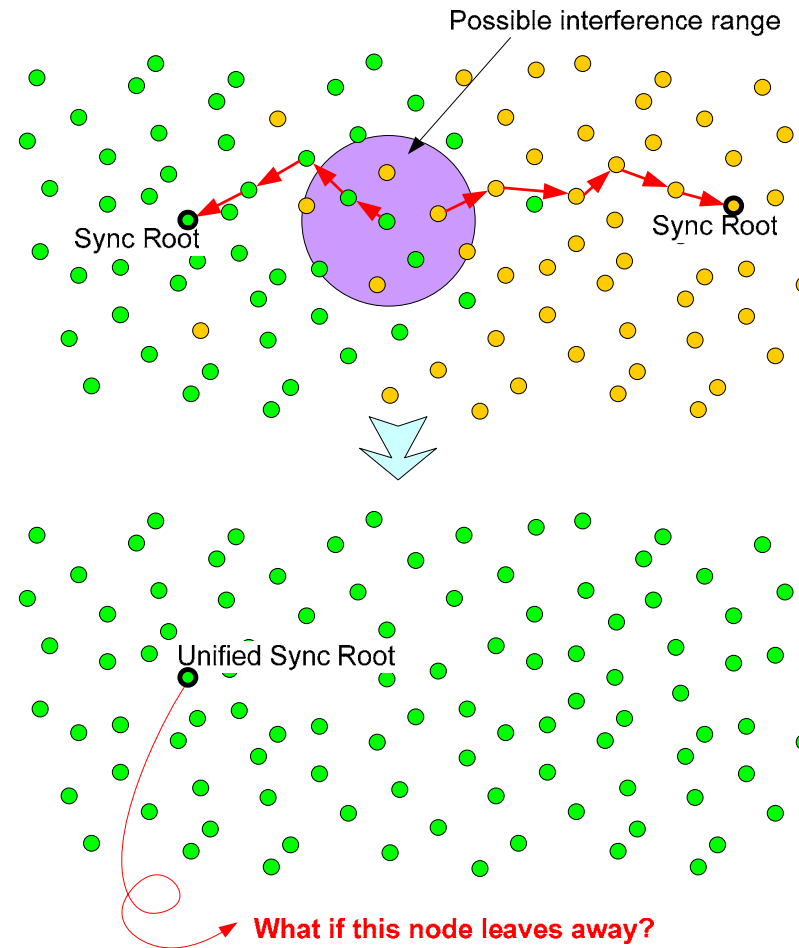
# Centralized Piconet Merging



## 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

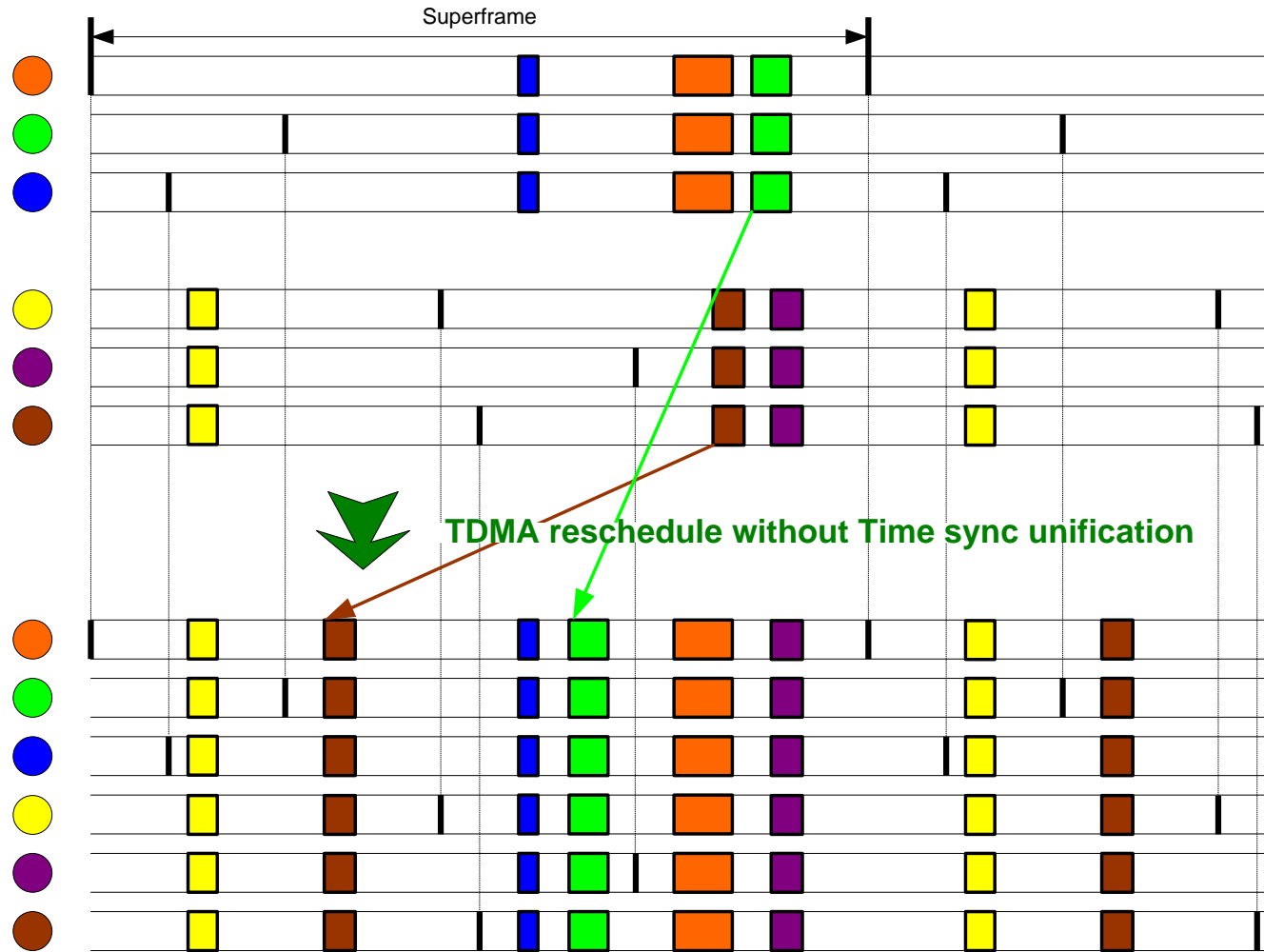
# Problems of Centralized Piconet Merging



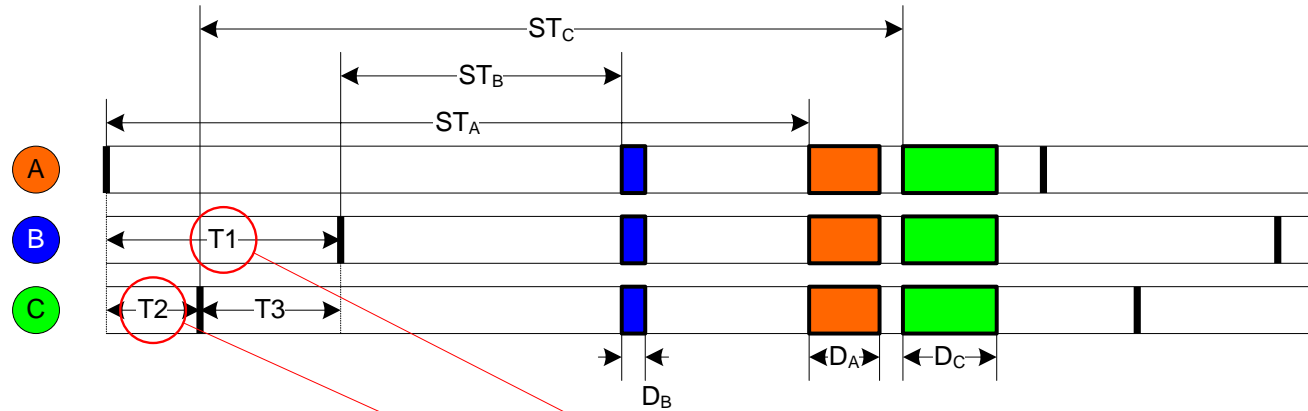
# Resolving Approach

- Distributed scheduling
  - Only local consensus is required
    - No sync root
  - Exchanging time information between neighboring piconets
- Loose synchronization
  - Just avoiding slot allocation over the slot duration allocated by neighboring piconet
  - 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
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TDMA schedule Table **A**

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

TDMA schedule Table **B**

Addr	# hop	Offset	Slot Start	Slot Dur	Seqno
<b>A</b>	1	$-T1$	$ST_A - T1$	$D_A$	$SN_A$
<b>B</b>	0	0	$ST_B$	$D_B$	$SN_B$
<b>C</b>	1	$-T3$	$ST_C - T3$	$D_C$	$SN_C$

TDMA schedule Table **C**

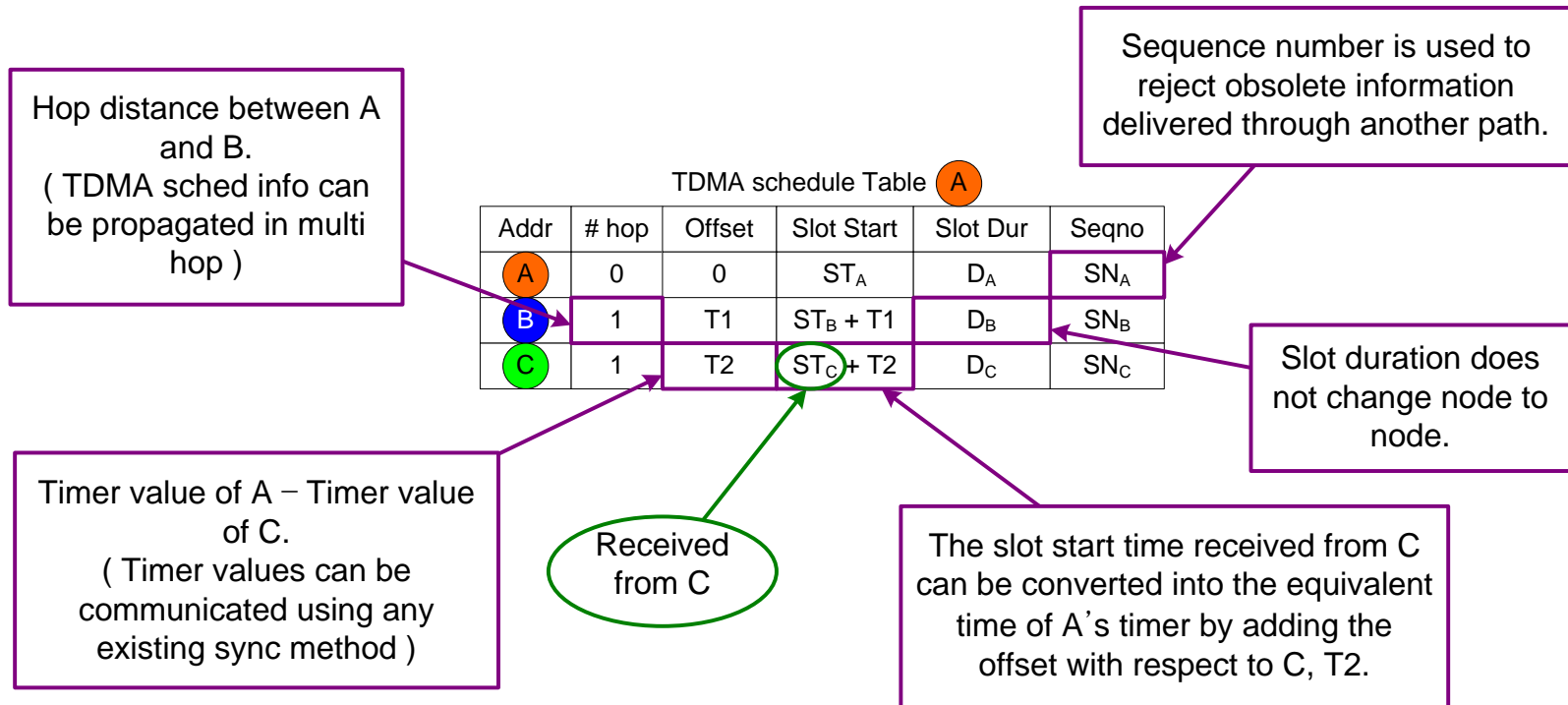
Addr	# hop	Offset	Slot Start	Slot Dur	Seqno
<b>A</b>	1	$-T2$	$ST_A - T2$	$D_A$	$SN_A$
<b>B</b>	1	$T3$	$ST_B + T3$	$D_B$	$SN_B$
<b>C</b>	0	0	$ST_C$	$D_C$	$SN_C$

# Offset Calculation

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



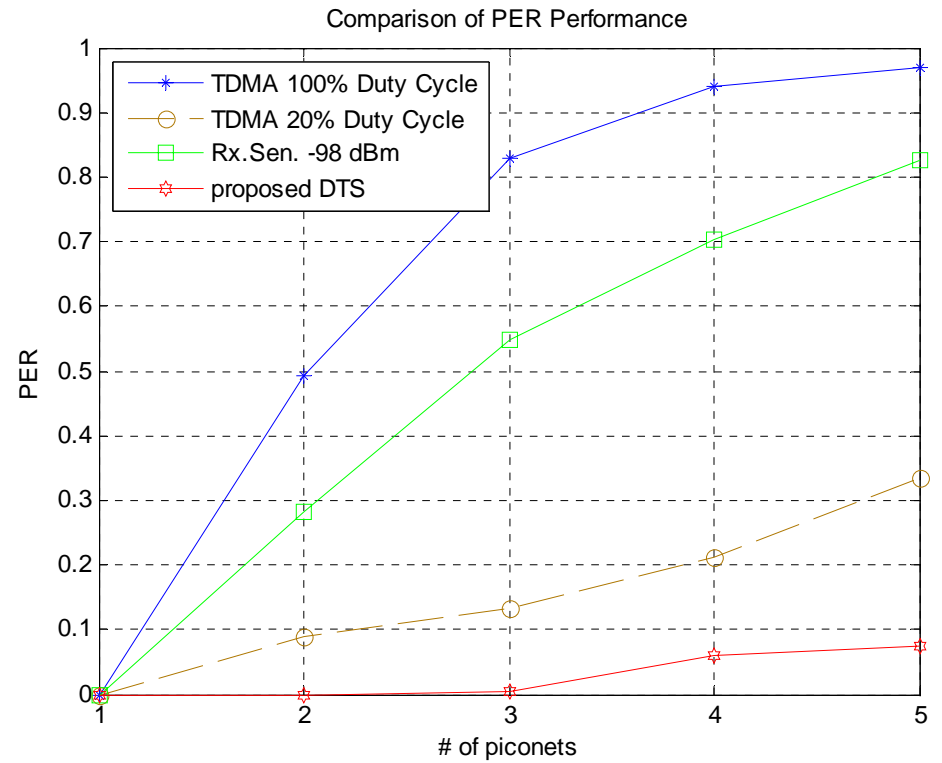
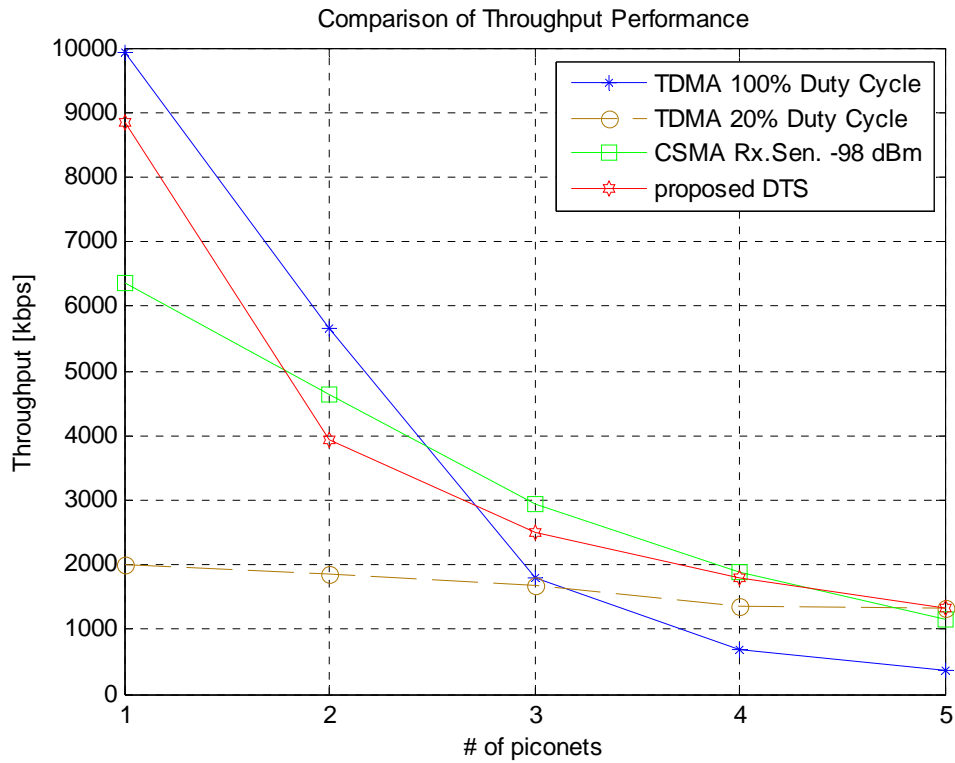
# TDMA Schedule Table Calculation



## Simulation Setup

- 10Mbps system
- # of nodes = 8
- CSMA/CA parameters
  - CCA threshold = 10dB
  - Rx. Sensitivity = -98dBm
- Time information broadcasting
  - Sent at beacon time with robust coding

# Simulation Results



# Conclusion

- TDMA
  - Bandwidth efficient
  - 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
- Uncoordinated interference problem
  - When two piconets are out of the communication range while still in the interference range of each other
  - Partially solved with multi hop coordination
  - Fundamentally solved with two level Tx power control

# Welcome Merger

- Super-frame
  - CFP (Contention Free Period)
  - CAP (Contention Access Period)
  
- Partial proposal
  - Only SOP 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.

**Thank You!**