IEEE P802.15
Wireless Personal Area Networks

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Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)		
Title	**802.15.6 MAC Partial Proposal : Distributed TDMA Scheduling for SOP**		
Date Submitted	4th May, 2009		
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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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1. Motivation

1.1. 802.15.6 BAN applications for high data rate service

802.15.6 standard covers various applications[1] for companies, service providers, and chip makers. It is generally accepted that consumer electronics or entertainment service has more huge market than medical device market. For the successful business of wearable entertainment service by using 802.15.6 standard, we need killer-application such as streaming video goggle or A/V video recording. Goggle type display will be a new form of the future mobile station which provide video source as an entertainment content. A/V video recording will give the safety as like CCTV or inform the exact information about the patient for the doctor.

1.2. BAN piconet environment

BAN application is serviced usually when other people locate nearby the user. This condition induces much interference from neighboring piconets. And, frequent encounter with other piconets makes the dynamic condition by which we cannot control the system easily.

1.3. Time resource sharing

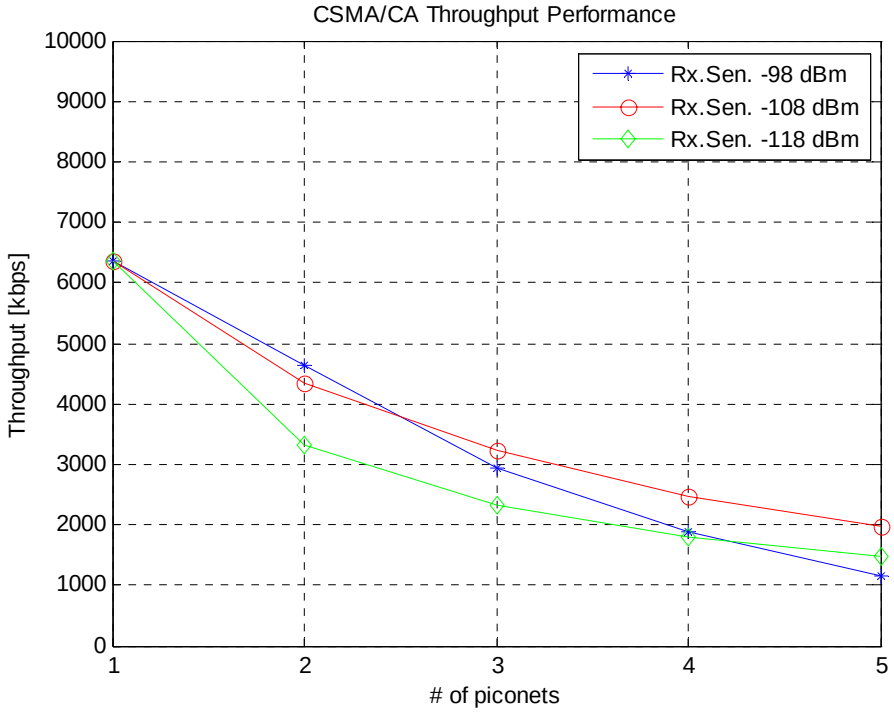
SOP is a important issue. Time resource sharing is required to avoid collision by interferences from neighboring piconets. Collision is the main reason to degrade QoS performance such as PER (packet error rate) or delay. Above all, there are a few number of frequency bands when we want to use UWB band which is opened globally over 7.25~8.5GHz[2].

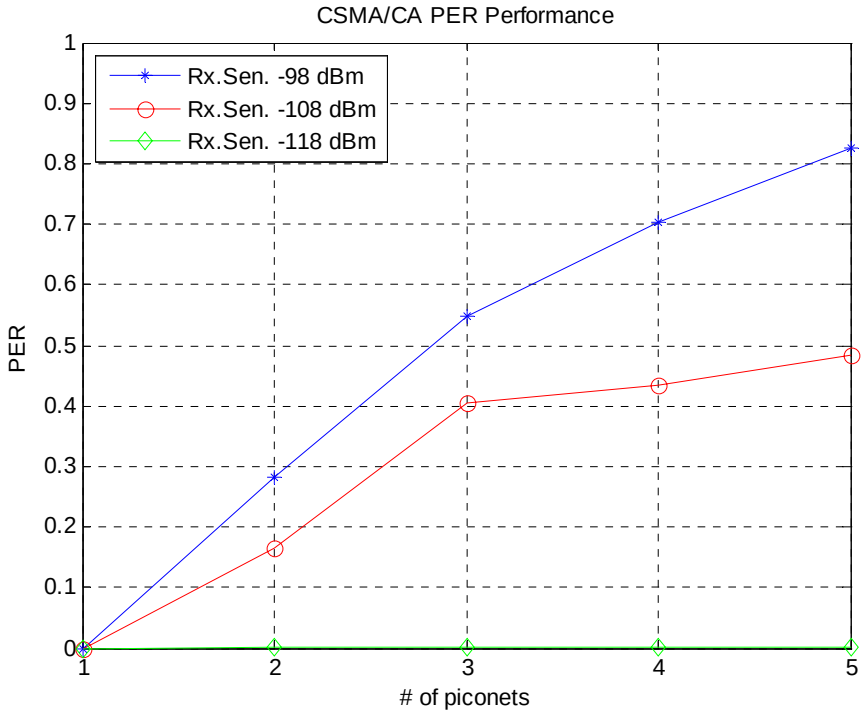
2. Possible solutions for SOP

If we use ISM band such as 2.4GHz, there is number of frequency bands for the system. So, we can utilize frequency bands for SOP by changing assigned band when collision occurs. However, frequent change of band makes the system complex and causes high power consumption. Some other approach such as direct spreading spectrum, frequency hopping, or time hopping, can support only low data rate services. Contention-based access such as CSMA/CA can be regarded as solution. However, contention-based access is not easy to meet the delay constraint, or brings about hidden node problem. Specially, UWB system shows poor channel sensing performance. Channel sensing is also difficult when using MICS band or in the body shadowing condition.

3. Inter-piconet collision

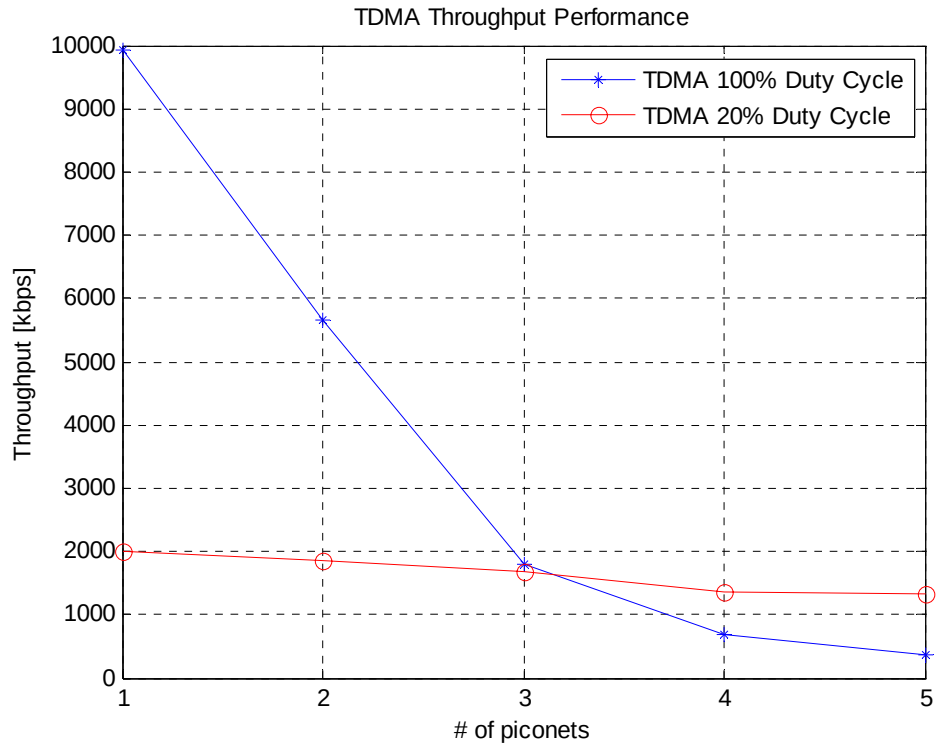
There are cases for inter-piconet collision. Collision between TDMA slots is not avoidable when any control is not existed. When TDMA slot and CSMA slot are collided, piconet using CSMA can reduce collision ratio by channel sensing. However, the performance may be degraded according to receiver sensitivity. You can see that the CSMA performance goes bad when receiver sensitivity goes high as following figures.

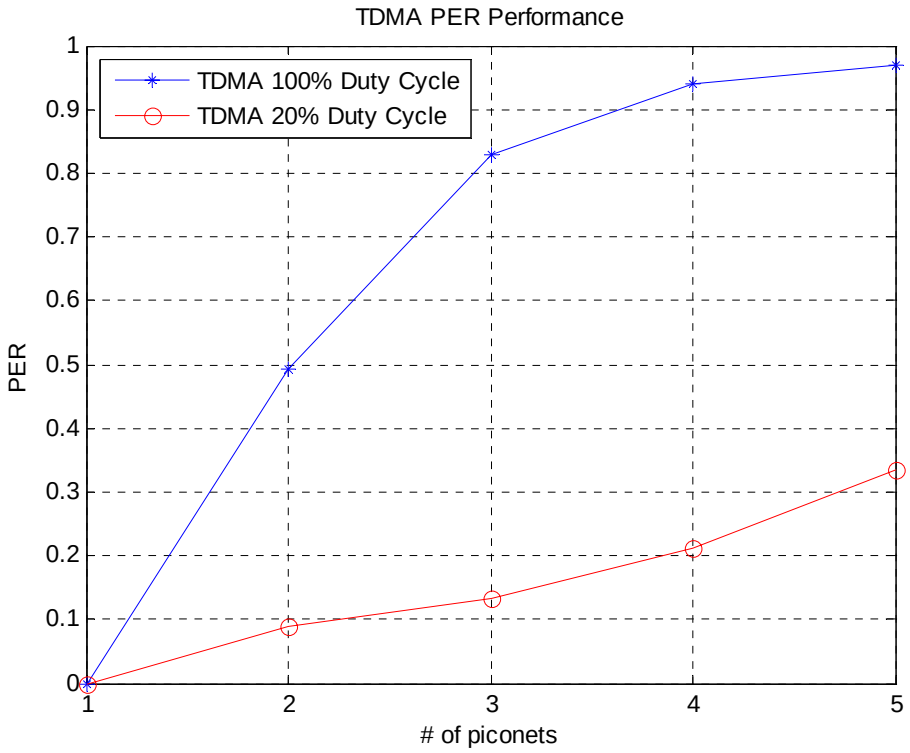

CSMA/CA Throughput Performance
Throughput [kbps]
# of piconets
Rx.Sen. -98 dBm
Rx.Sen. -108 dBm
Rx.Sen. -118 dBm
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
1
2
3
4
5


CSMA/CA PER Performance
PER
# of piconets
Rx.Sen. -98 dBm
Rx.Sen. -108 dBm
Rx.Sen. -118 dBm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5

For your information, receiver sensitivity of 802.15.4a UWB PHY is 85dBm (for 1Mbps) or 91dBm (for 250kbps). We used a PER performance of specific PHY to get intuitive comparison. Collision case between CSMA slots is same as the condition of CSMA in single piconet.

We can consider TDMA due to its guaranteed QoS, high channel efficiency and very low power consumption on behalf of CSMA, if there is some good methods to synchronize piconet timing and scheduling time slots of piconets. High packet error rate is probable without timing control as following figures.

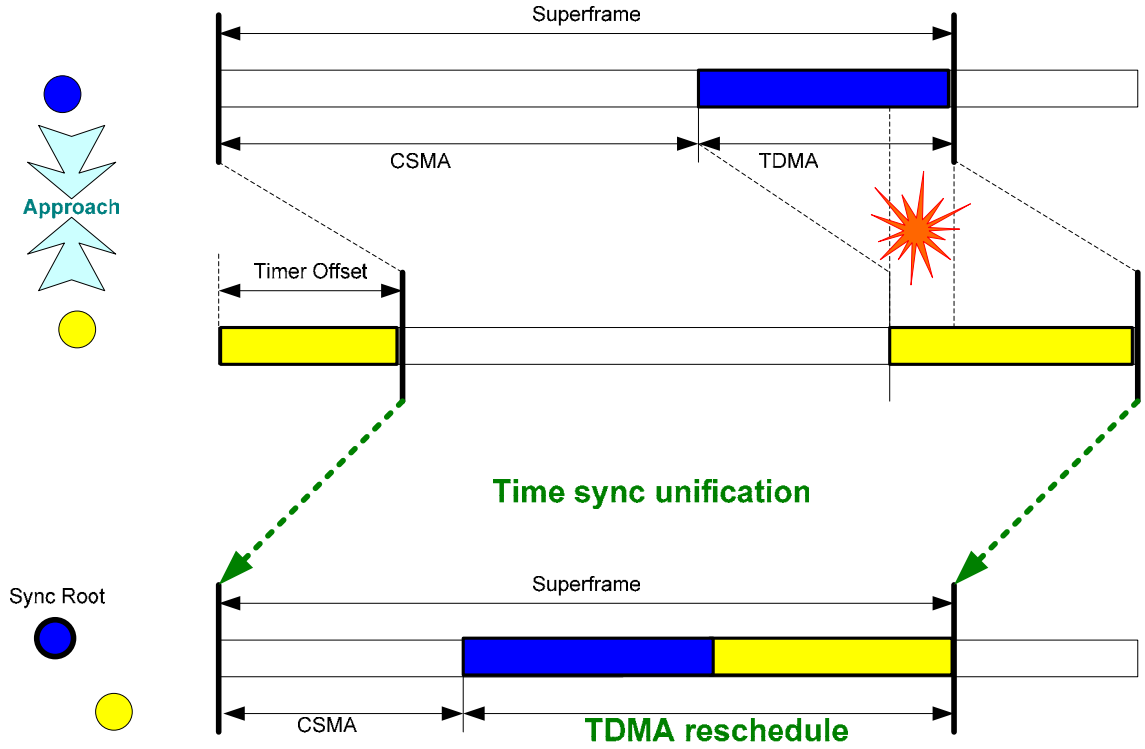


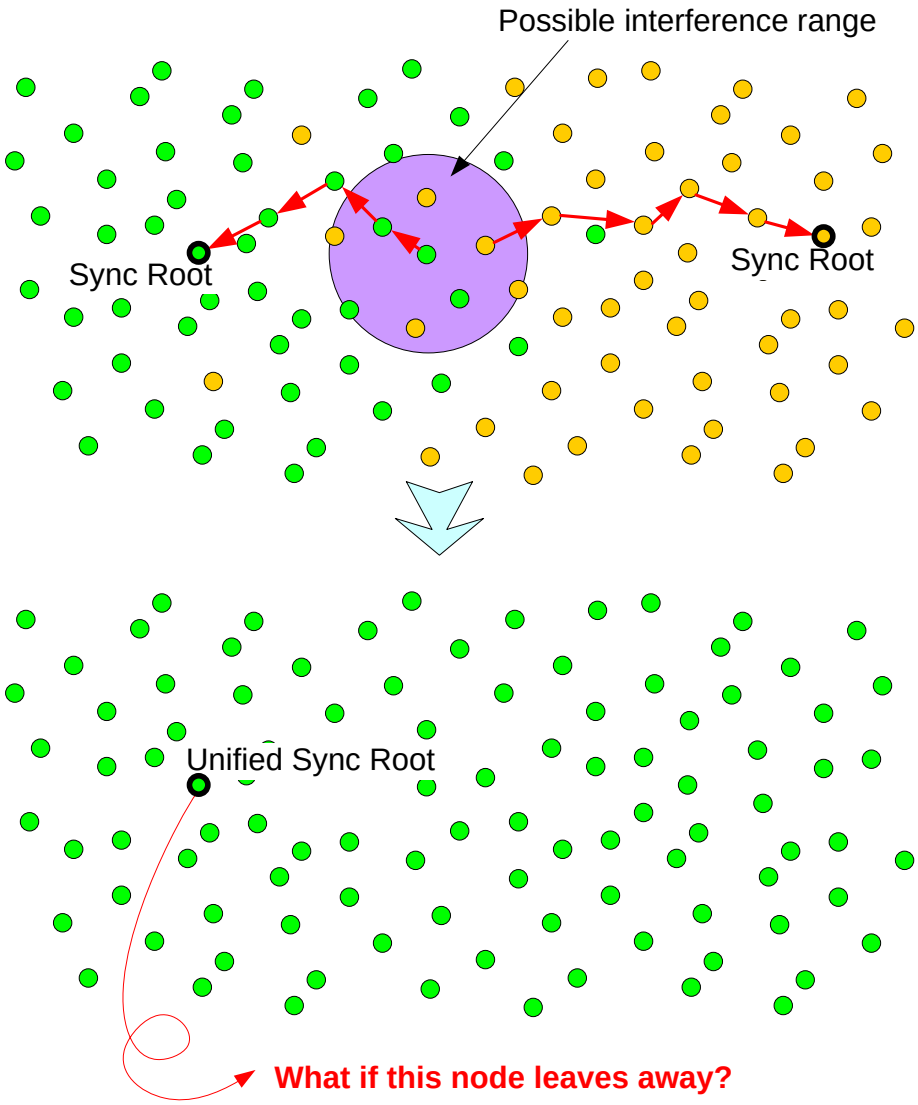


Even though we adjust duty cycle as 20%, collision occurs and causes inevitable packet error.

4. Centralized Piconet Merging

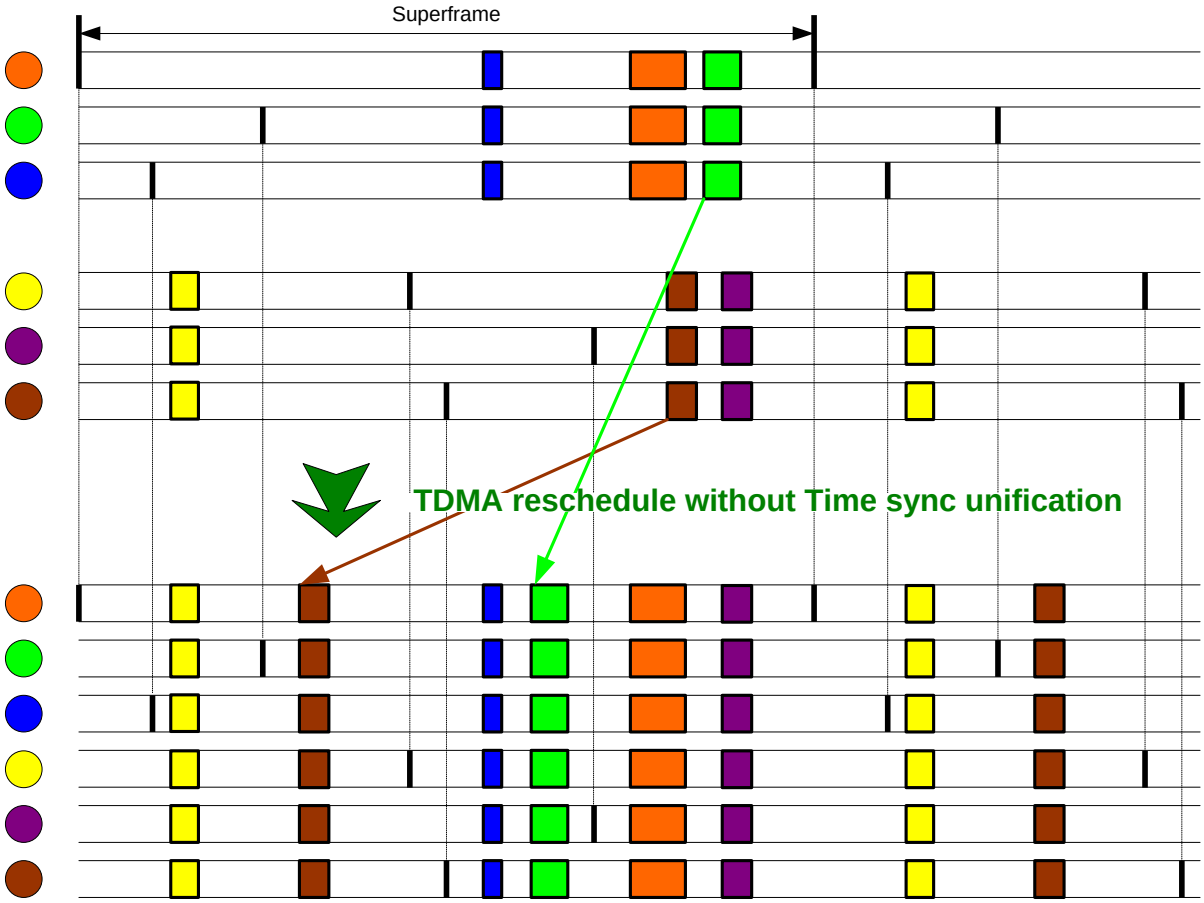
TDMA based piconet merging is generally approached by centralized method for static mobile sensor nodes. However, centralized piconet merging has problems in the dynamic and dense piconet condition. So, fine synchronization is very difficult. Centralized approach is able to apt failed due to its low scalability and large signal overhead. And frequent change of sync root node makes the system unstable.


Superframe
CSMA
TDMA
Approach
Timer Offset
Time sync unification
Sync Root
Superframe
CSMA
TDMA reschedule



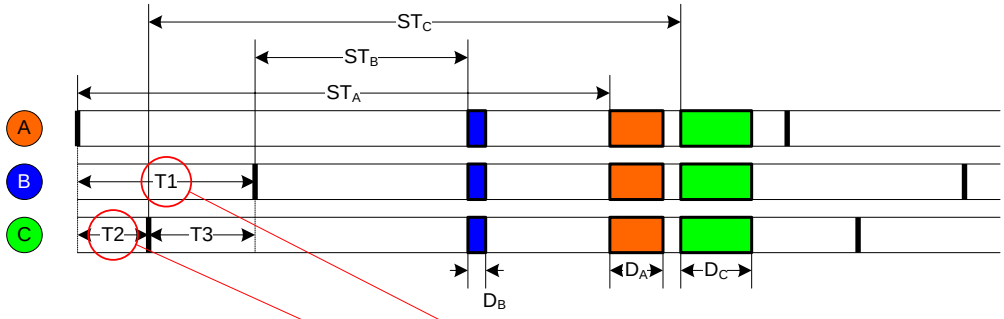
5. Distributed Approach To Resolve Piconet Merging

Distributed manner can be the alternative of centralized approach. To perform scheduling and exchanging time information by the basis of the local consensus can overcome the limitation of centralized time scheduling. And, assuming loose synchronization to schedule time resources can make the problem a naïve lamb. Just avoiding slot allocation over the slot duration allocated by neighboring piconet is enough for the goal. We don't need to fit at slot level for fine synchronization.



6. Distributed TDMA Scheduling for SOP

For the local consensus and decision for slot allocation, we use the method which is said as local time offset exchange as following. Piconets can probe the timing information and calculated time offset by the existing method such as time stamp of 802.11 or beacon Tx. time control of 802.15.4. Calculated time offset is transmitted to neighboring piconets by the form of TDMA advertisement message what we define. TDMA advertisement message contains node address, number of hops, TDMA slot starting time, TDMA slot duration and sequence number. Piconet manages TDMA schedule table by exchanging TDMA advertisement message.



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

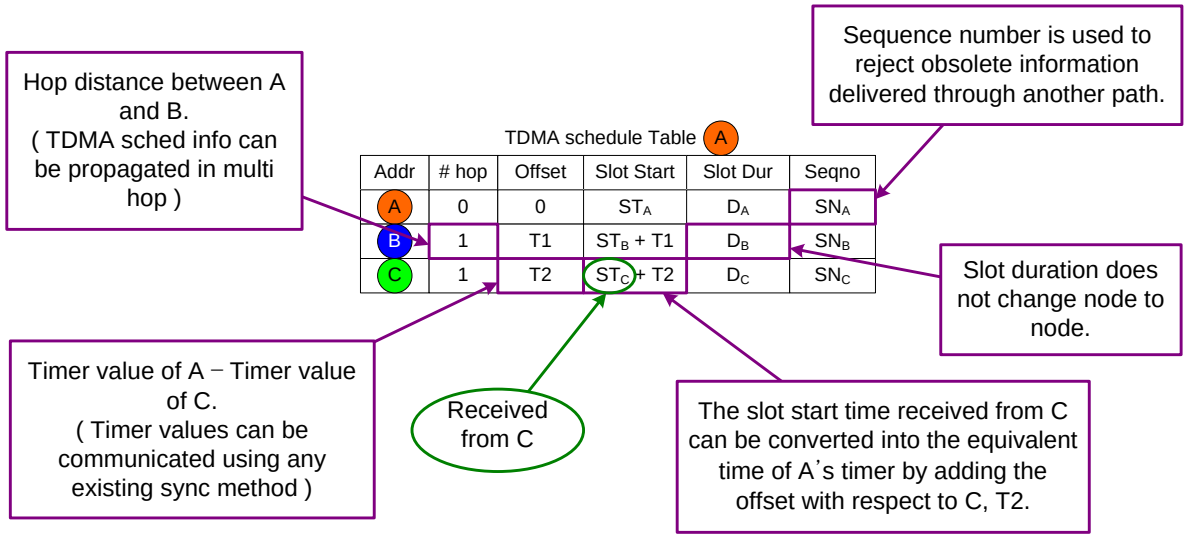
TDMA schedule Table B

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

TDMA schedule table is calculated as following.



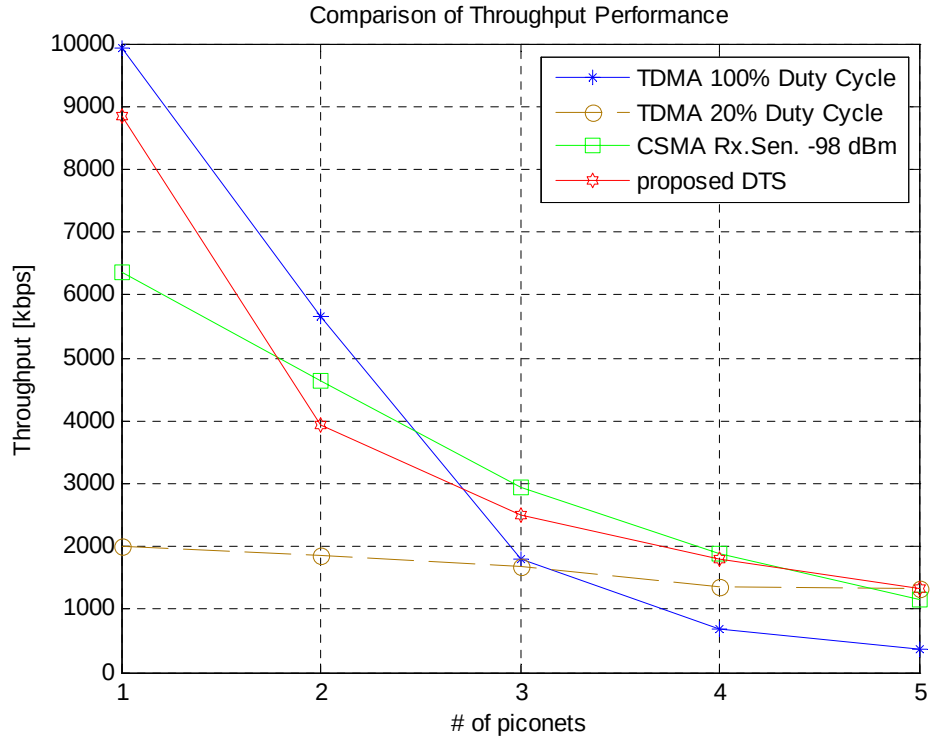
7. Simulation and Performance Results

7.1. Simulation setup

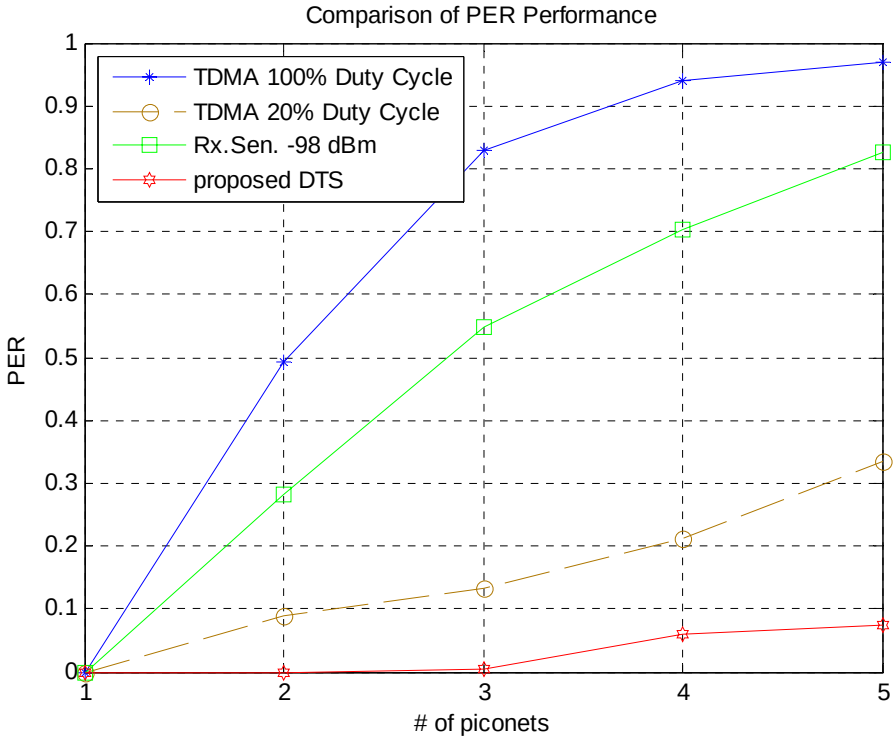
We decides the simulation parameters 10Mbps for streaming service, 8 nodes, 10dB CCA threshold, -98dBm Rx. sensitivity. And, time information broadcasting is sent at beacon time with robust coding to be endure interference from other piconets.

7.2. Simulation results

Simulation results show that proposed DTS (Distributed TDMA Scheduling) has a throughput comparable to the throughput of CSMA/CA in the 5 piconets case.



Proposed DTS also shows the best PER performance. PER of CSMA/CA is bad due to high Rx. sensitivity. Even though low duty cycling is applied, PER goes high to 30% when number of piconet increases by uncoordinated collision. PER of the proposed DTS can avoid collision by distributed coordination and get a small PER under 10%.



8. Conclusion

The proposed DTS (Distributed TDMA Scheduling) for SOP is designed for the BAN piconet condition to avoid interferences from other piconets. TDMA is chosen for its natural bandwidth efficiency, dynamic allocation, and delay bounded feature. We can support multiple piconets for high data rate service by distributed TDMA scheduling. This method will be useful for not only UWB systems but also some narrow band systems for its QoS supporting feature.

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.