A Spectrum Etiquette Protocol for Efficient Coordination of Radio Devices in Unlicensed Bands

Xiangpeng Jing and D. Raychaudhuri

WINLAB, Rutgers University

Outline

- Overview of spectrum management in unlicensed bands
- Spectrum etiquette system concept
- Etiquette protocol details: Common Spectrum Coordination Channel (CSCC)
- Experimental results for proof-of-concept
- Conclusion and future work

ISM Band Spectrum Allocation

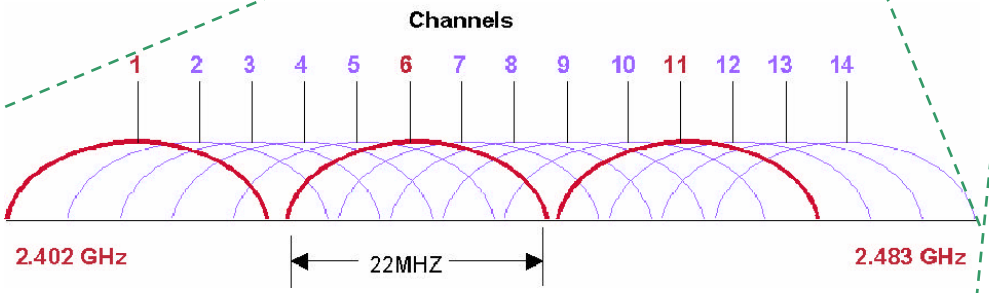
Industrial Scientific Medical band

902-928MHz

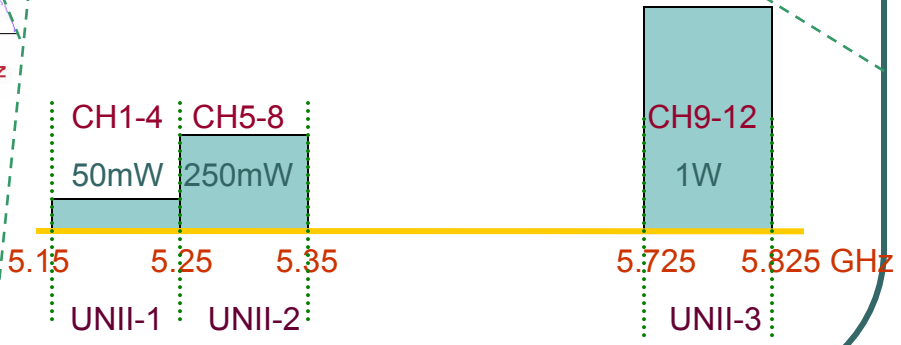
2.4-2.483GHz
(America)

5.15-5.35GHz
5.725-5.85GHz

Other ISM
24GHz, 60GHz

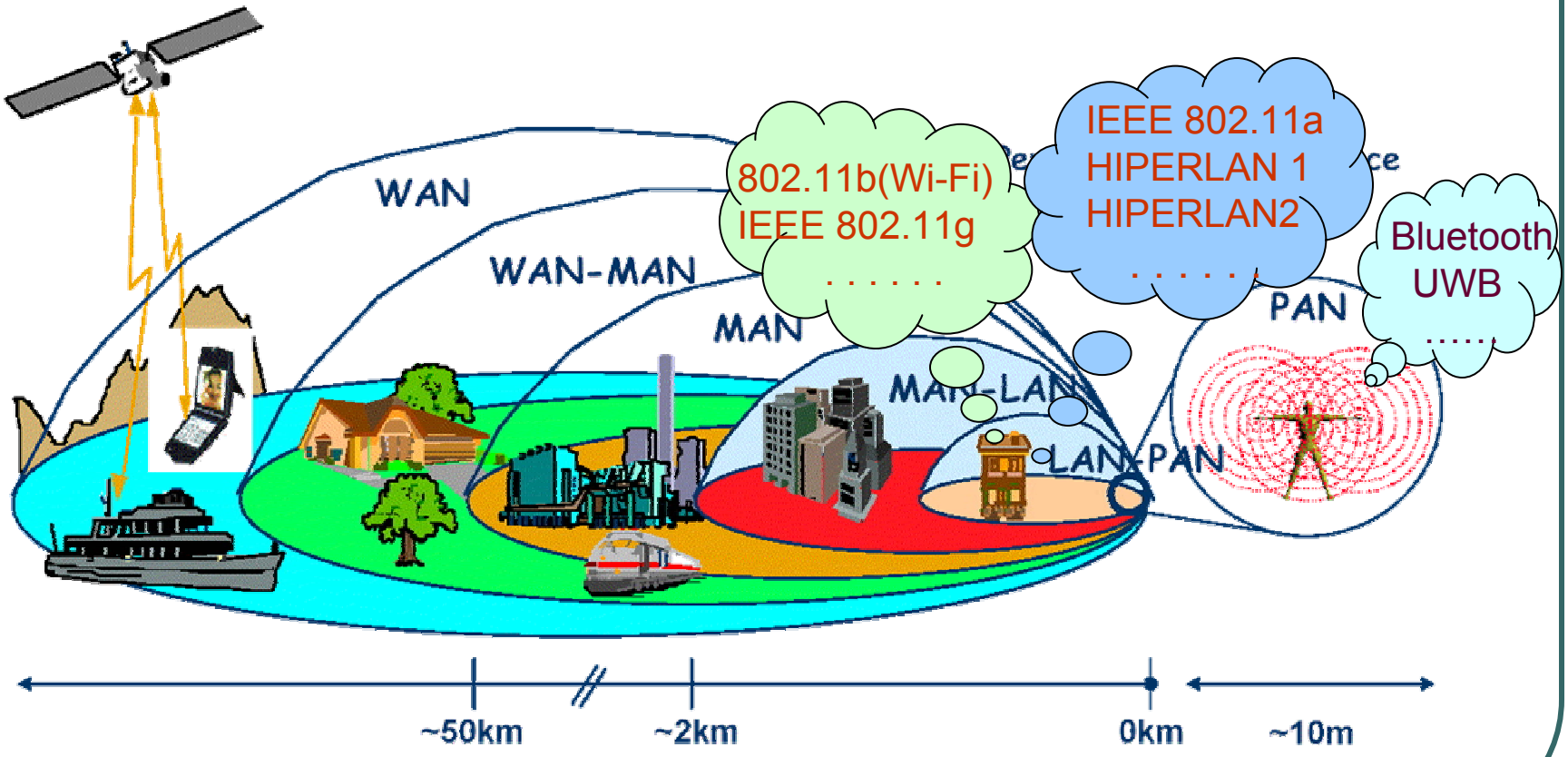


802.11b: 14 (11 under FCC) channels

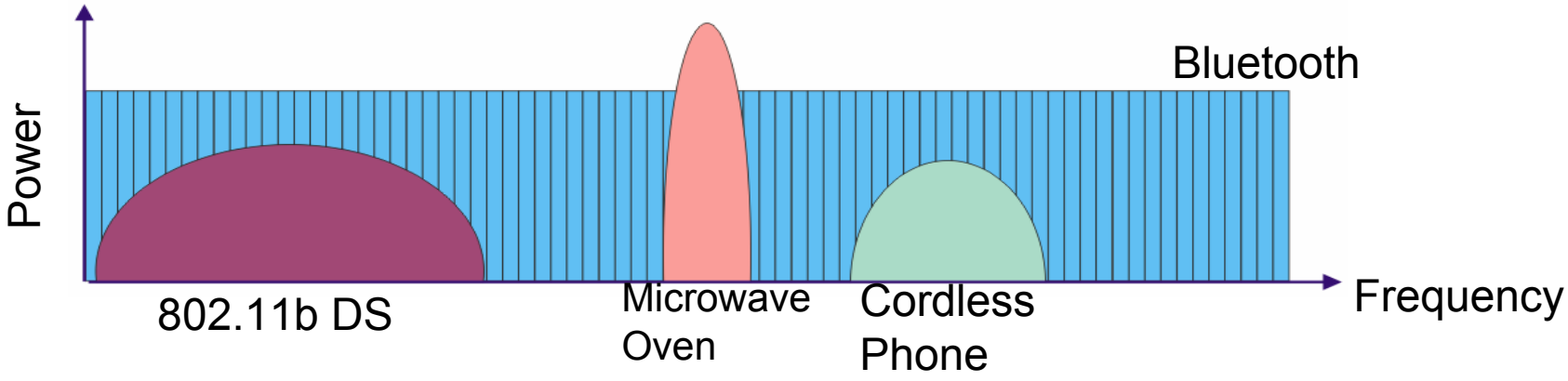


802.11a(US): 8 channel (UNII-1 & UNII-2)

Typical Network Scenarios

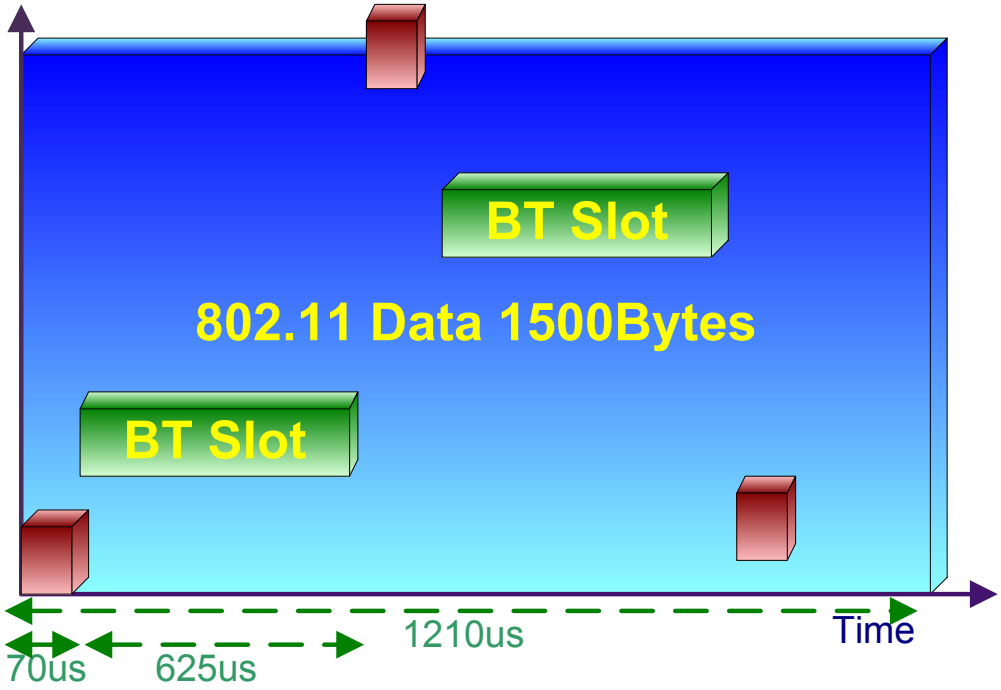


Interference Scenarios at 2.4GHz Band



- WLAN: 802.11b DSSS, 11 channels at 5MHz interval, covers ~100m (11Mbps) and ~400 (1Mbps).
- Bluetooth: FHSS, hopping rate at 1600hops/sec, 79 hopping channels at 1 MHz wide each, covers ~10m (low power) and typically covers ~10m.

Insight Into WLAN and Bluetooth

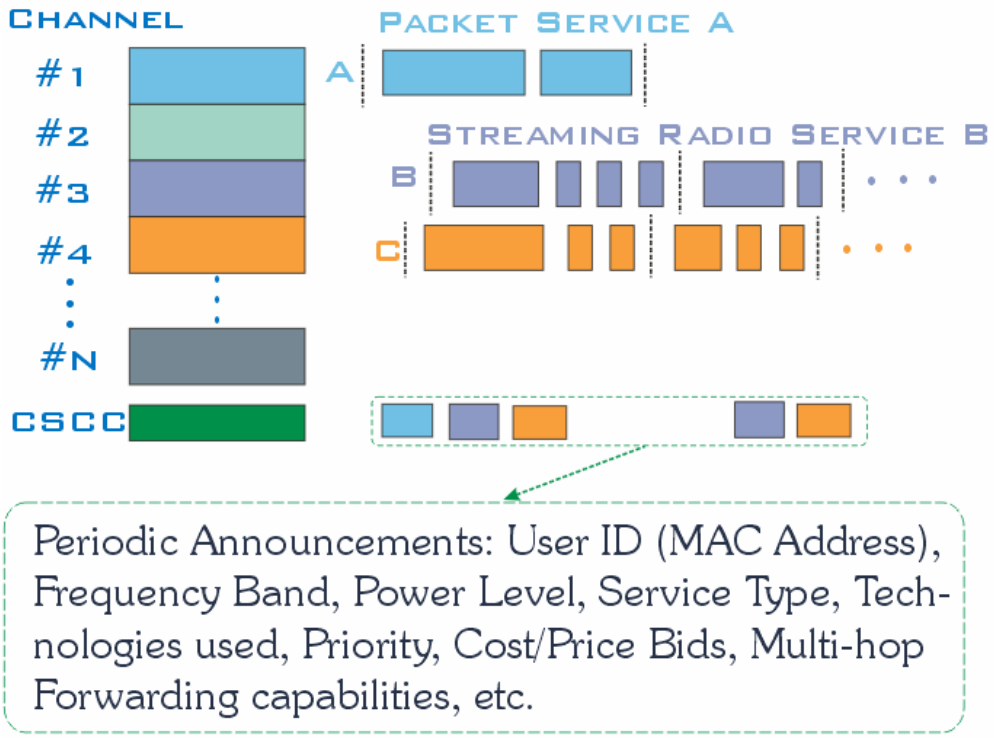


OBSERVATIONS:

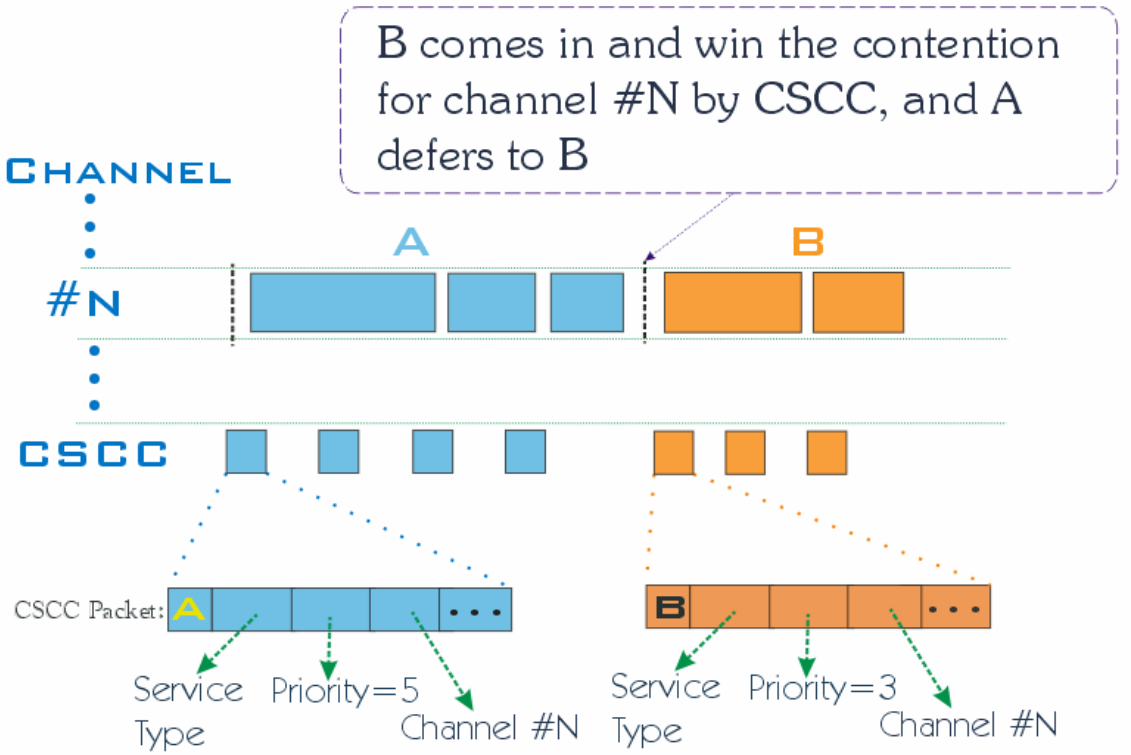
- A DSSS 802.11 packet can overlap a number of BT slots
- BT hopping into WLAN band with certain probability
- Lower transmission range of BT makes it easier to suffer
- Larger 802.11 payload suffers more for throughput degradation, especially for TCP sessions

Spectrum etiquette system concept

CSCC(Common Spectrum Coordination Channel) can enable mutual observation between neighbor radio devices by periodically broadcasting spectrum usage information

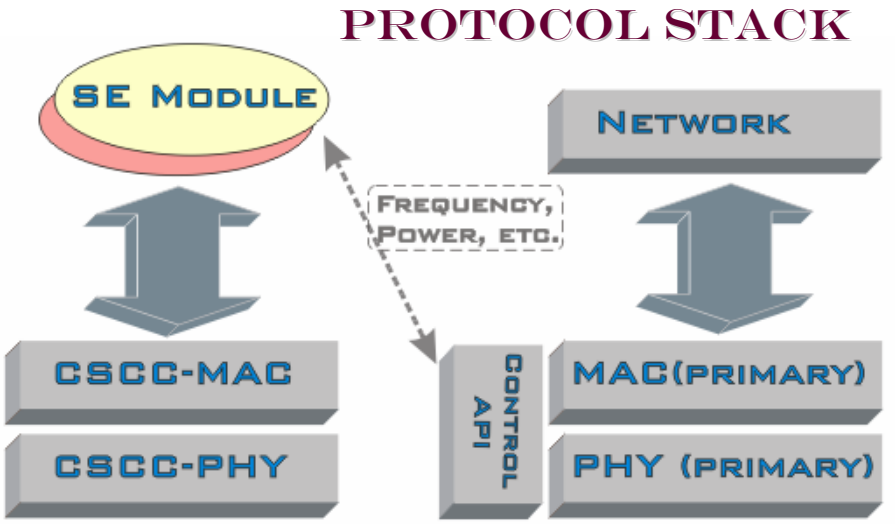


An Example of CSCC with a priority etiquette policy



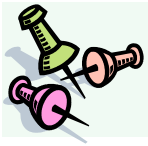
- A is taking channel Fn with a lower priority
- B comes in by competing with A for channel Fn with a higher priority
- By CSCC, contention/interference is resolved and A defers to B

CSCC Protocol Details



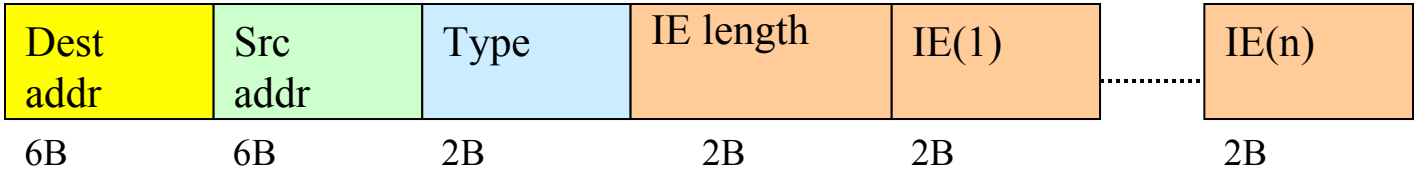
CSCC-PHY: 1Mbps 802.11b with 10 mW power can transmit 50~100 meters, edge-of-band operation

CSCC-MAC: 802.11 MAC based simple periodic broadcast (on-demand) protocol with random cycle (100ms~seconds) to eliminate repeated collisions



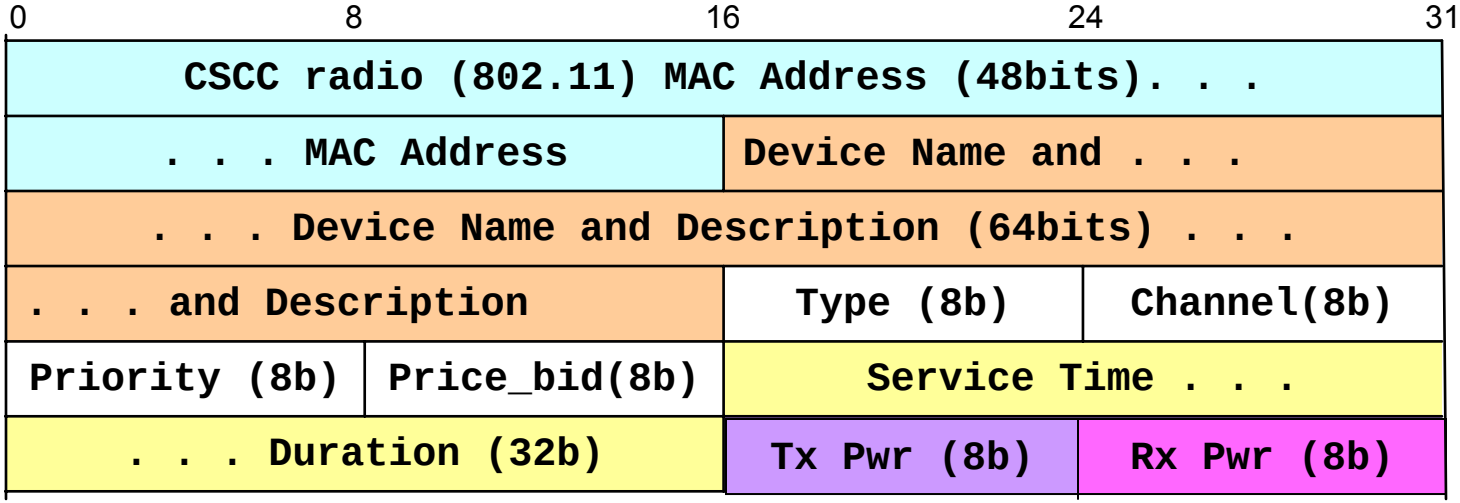
An extra cheap narrow band radio is well worth the improved utilization of public spectrum.

CSCC Packet Format



CSCC-PKT: A standard Ethernet packet format with control payload (consisting of variable length information elements)

AN EXAMPLE FOR WLAN-BT DEMO



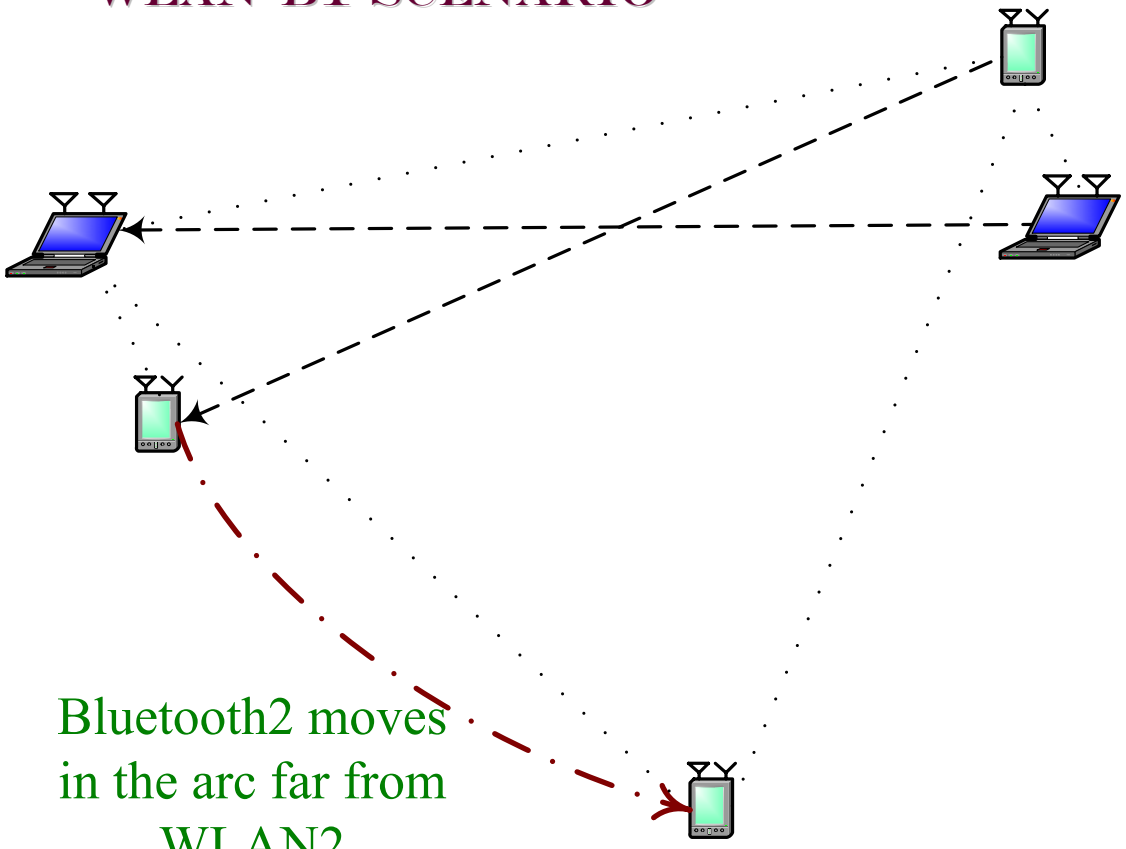
Etiquette Policies

- Contention for resources (channel/time /frequency/power) is resolved based on etiquette policies
- Priorities based on class of services/users
- Dynamic pricing (based on auctions): users offers to pay a price for access spectrum resources

OPEN RESEARCH ISSUES:
Optimization for radio resource allocation policies

Proof-of-Concept Experiments

WLAN-BT SCENARIO



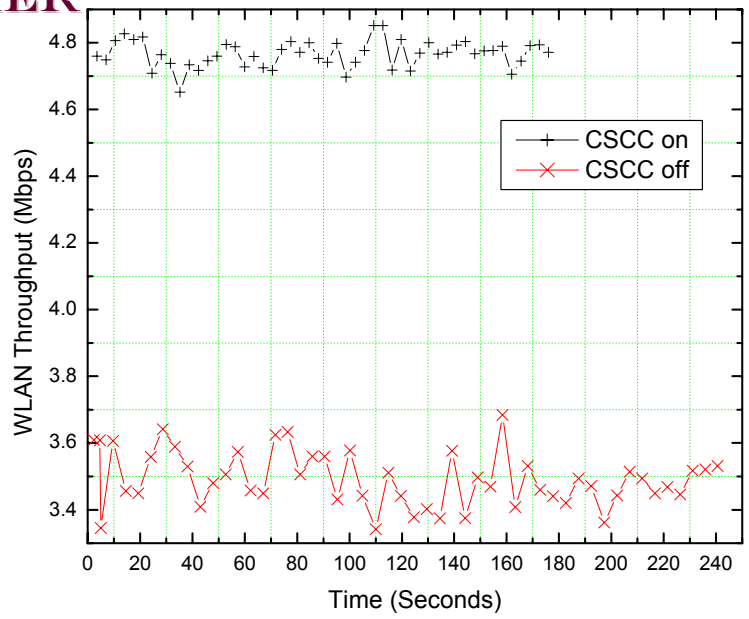
- Different devices with dual mode radios running CSCC
- d=4 meters are kept constant
- Priority-based etiquette policy

Experimental Parameters

	WLAN nodes	Bluetooth nodes
Mobility	Static without mobility	BT1 static, BT2 position varies
Traffic Model	100M bytes data by TCP	1.5M bytes data using Stop-and-wait scheme
MAC protocol	IEEE 802.11b at 11Mbps	Bluetooth ACL data link
Data card	Cisco Aironet 350 series DS (at channel #1)	Ericsson BT w/ USB (hopping over whole band)
CSCC MAC	IEEE 802.11 & periodic announcements at 1Mbps	
CSCC card	Cisco Aironet 350 series DS (at channel #11)	

Results: Throughput Trace (1)

WLAN HAS HIGHER PRIORITY:

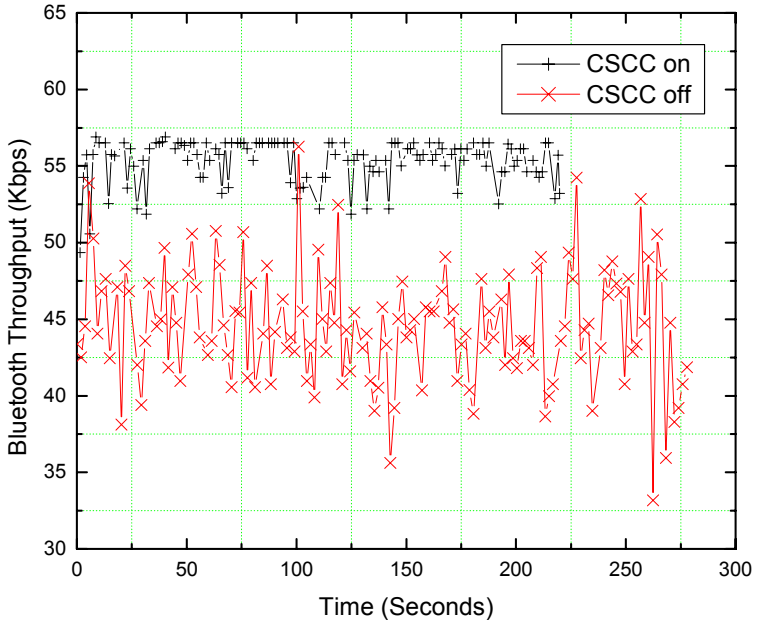


WLAN session with BT2 in initial position

- TCP can perform badly in interferenced wireless links due to its window scheme

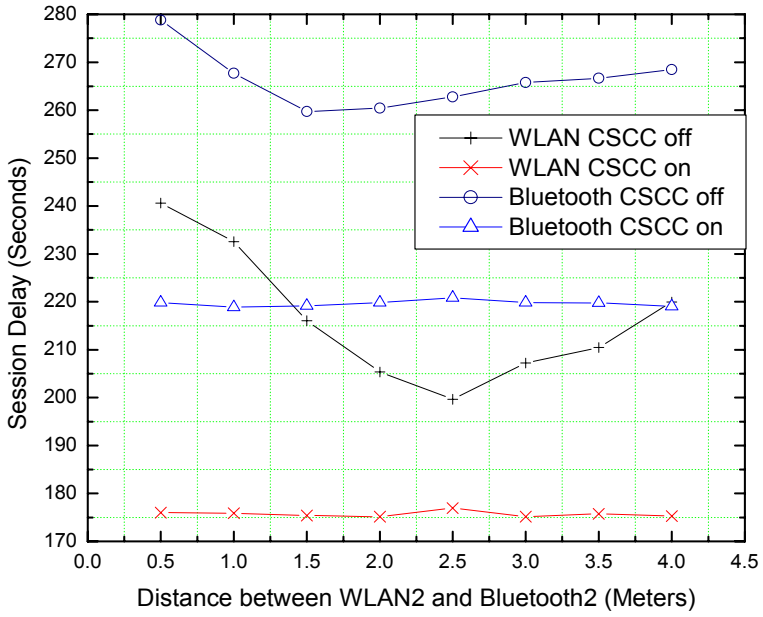
Results: Throughput Trace (2)

BLUETOOTH HAS HIGHER PRIORITY:

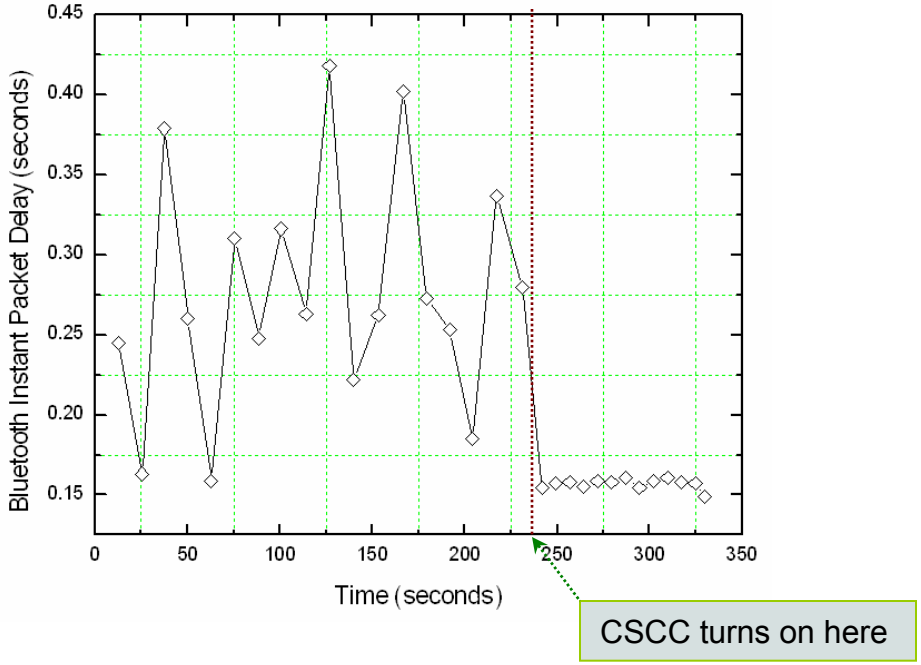


BT session with BT2 in initial position

Results: Session&Packet Delay



Average session delay with and w/o CSCC vs. distance parameter



Instantaneous packet delay for BT with CSCC turned on at t=230s

Conclusion

- CSCC: a simple way for radio devices with different technologies to coordinate with each other
- Dual- mode radio allows devices announcing their own parameters by using a common edge channel
- Radio resources can be allocated in a fair and spectrally efficient manner based on etiquette policies
- Experiments on a WLAN- BT scenario show achievement in throughput and delay performance

Future Work

- Evaluate various levels of spectrum coordination by both simulation and experiments
- Develop more complex collaborative spectrum sharing methods involving ad hoc networking and power control
- Consider multi-hops with CSCC forwarding
- Optimization of etiquette policies

Thank you!