Spectrum Etiquettes for Short Range Wireless Devices Operating in the Unlicensed Band - A Proposal

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Joint work with

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Spectrum Policy: Property or Commons
Stanford Law School
March 2, 2003

Introduction

- Why etiquettes?
  - ‘Unlicensed’ is growing up
  - Experience in existing bands
  - Broader use requires better reliability
  - Coexistence of smart devices
- Goals
  - Establish common ground
  - Joint proposal to regulators
- Objectives today
  - Reality test our thinking so far
  - Improve the proposal
  - Build consensus

The Outlook

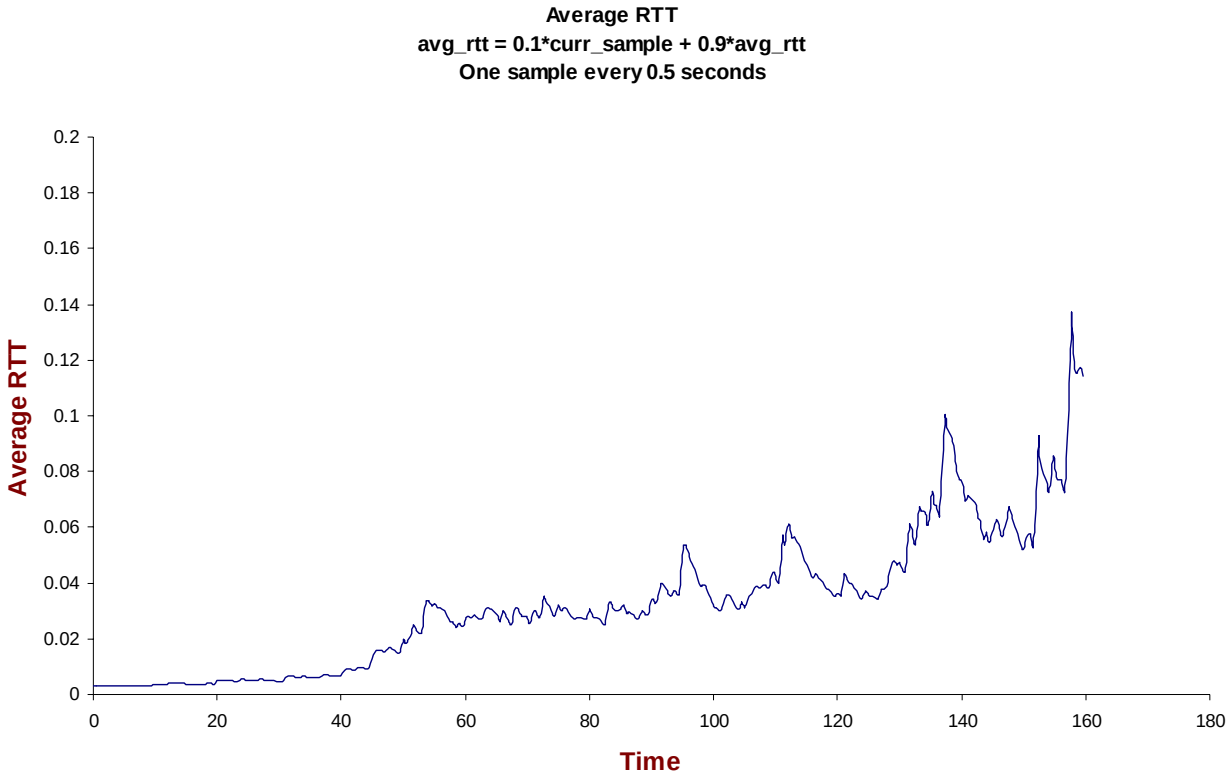
- Over time the number of wireless data devices will increase dramatically (e.g. sensors)
- Over time the demand and expectation from wireless connectivity will increase
- Current allocation of unlicensed bandwidth is not sufficient to meet these demands
- Need regulations to enable robust wireless data networks

Design Criteria

- Enable continued innovation
- Minimize mutual interference between transmitters
- Allow all devices to contend and gain some access
- Maximize spectrum utility
- Global solution

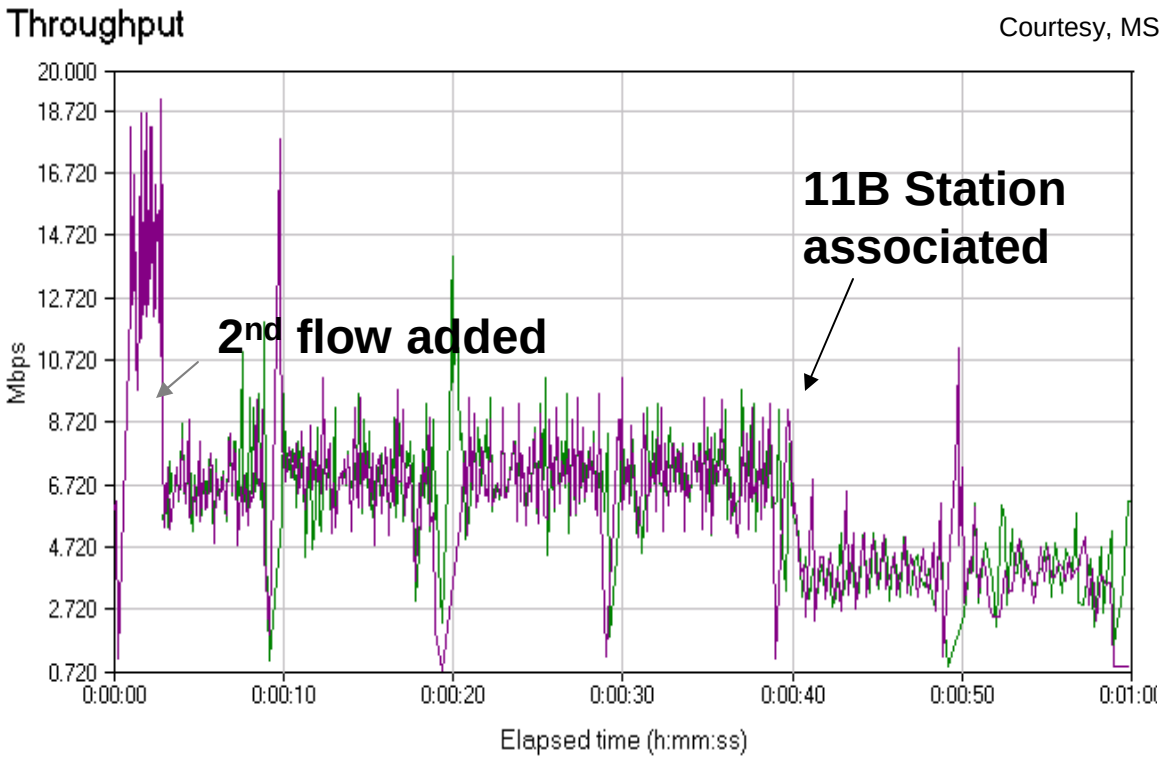
State of Art –
WiFi performance data…

Round Trip Delay versus Node Density



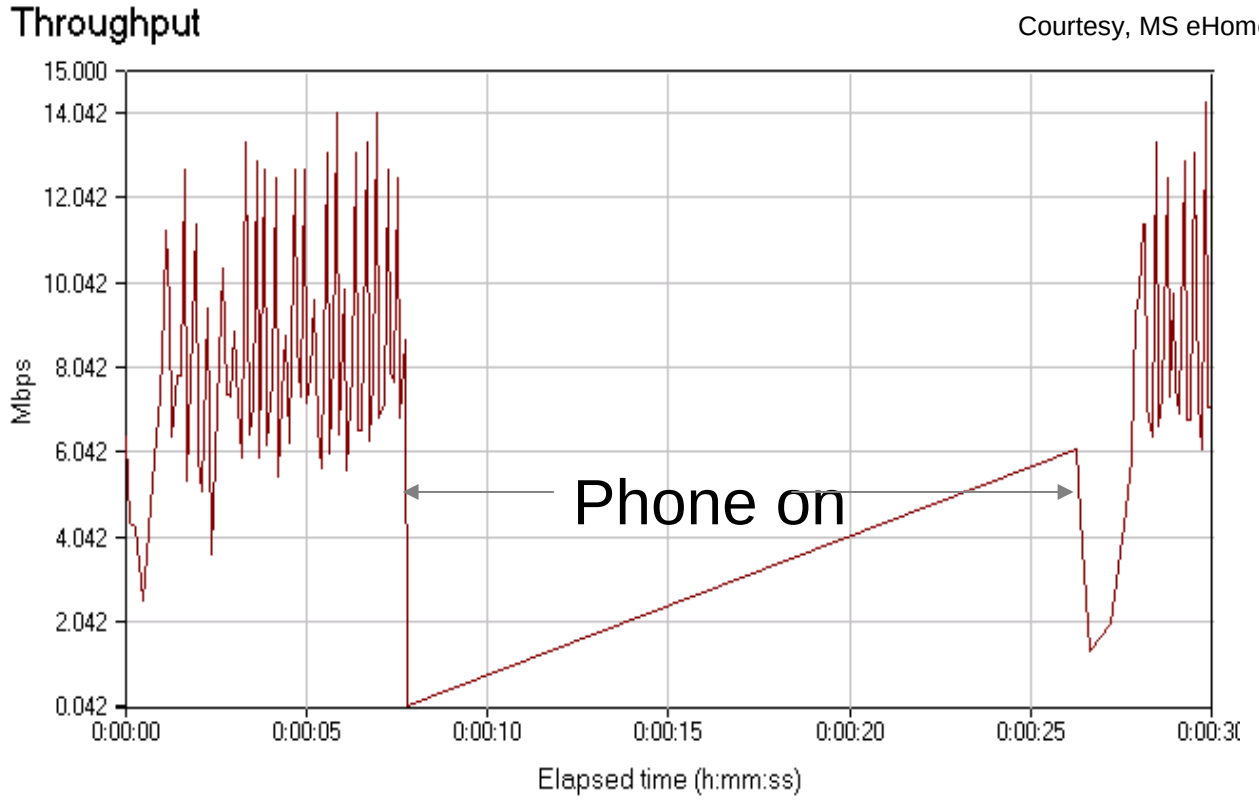
A new 100Kbps CBR connection starts every 10 seconds, between a new pair of nodes. All nodes hear each other.

Throughput versus number of flows



IEEE 802.11g (draft) in mixed configuration 2 flows with 11b node associated

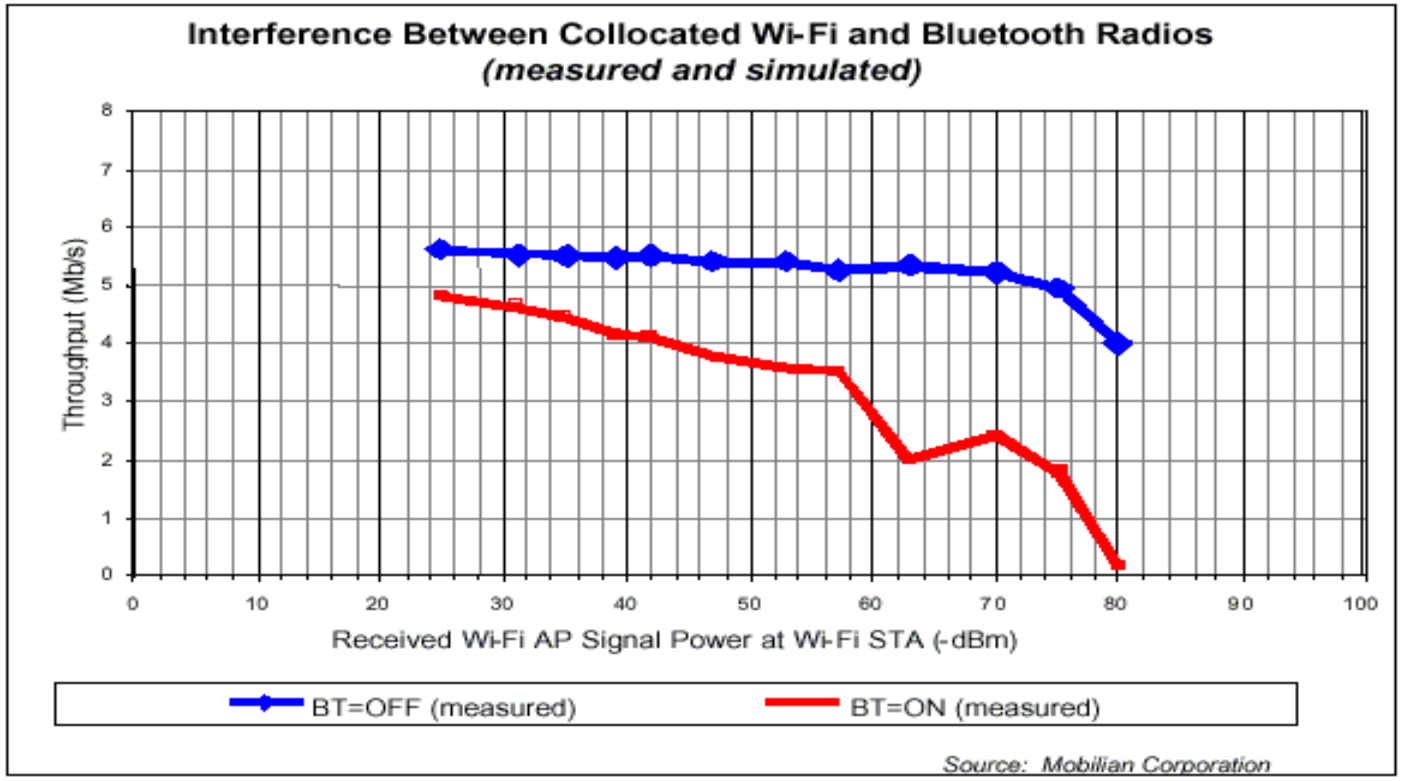
In the presence of other 2.4 GHz devices



Panasonic 2.4GHz Spread Spectrum Phone 5m and 1 Wall from receiver

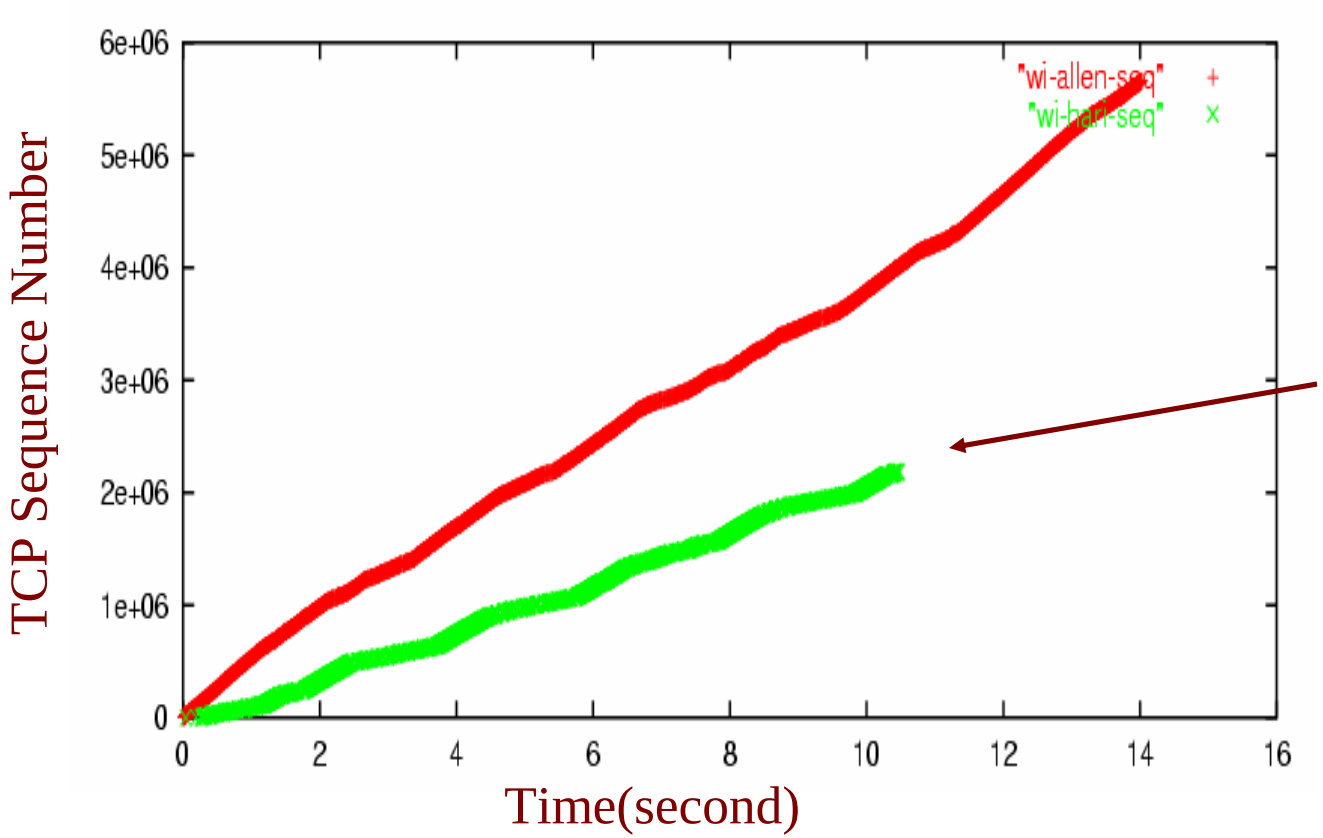
Colliding standards: performance degrades

Courtesy: Mobilian Corp.



Performance worsens when there are large number of short-range radios in the vicinity

Following rules and regulations but….



Adding BT to the mix

Two TCP Downloads From a 802.11 Access Point

Etiquette Proposal….

Design Criteria (repeat)

- Enable continued innovation
- Minimize mutual interference between transmitters
- Allow all devices to contend and gain some access
- Maximize spectrum utility
- Global solution

Design Goals

1. Allow continued innovation in the Physical (PHY) and Medium Access Control (MAC) layers
2. Minimize mutual interference between transmitters
3. Allow all devices to contend and gain access to the channel
4. Maximize spectrum utilization and capacity

   Note: goals 2 & 4 are related.

Promote harmonization of rules and regulations for spectrum management around the world

Constraints (self imposed)

– to facilitate operation of diverse wireless devices

1. Make no assumptions about receivers or their existence
   - Consider transmitters only

2. Make no assumptions about the channel
   - Channel may be symmetric or asymmetric

3. Make no assumptions about formats
   - Do not think in terms of bits, bytes, or frames – this is for higher layer protocols (e.g. TCP/IP)
   - Work with time, frequency, and power

Constraints → Limitations

- Etiquettes do not completely eliminate device interference
- Etiquettes do not address the inevitable reduction of throughput with increase in node density

Etiquette Proposal

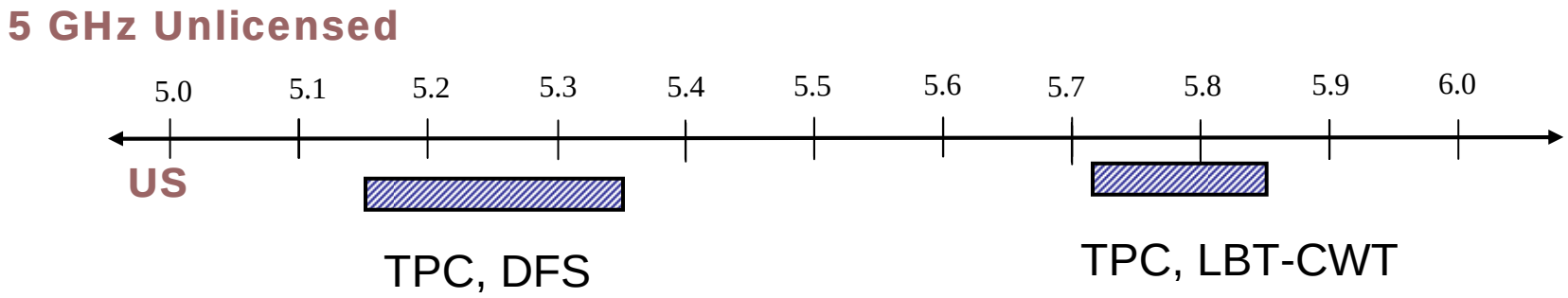
- Transmit Power Control (TPC)
  - Reduce interference between neighbors, increase capacity through increased spatial reuse
- Dynamic Frequency Selection (DFS)
  - Reduce destructive interference resulting from simultaneous transmissions
- Listen Before Talk with Channel Wait Time (LBT-CWT)
  - Eliminate the possibility of devices being shut out from using the spectrum

In addition….

Etiquette Proposal (cont.)

- TPC is applied to the entire unlicensed band
- DFS is applied to x % of the unlicensed band
- LBT-CWT is applied to (100-x) % of the unlicsensed band

For example,



Strengths and Rationale

Simplicity

- Easy to understand and enforce. Complicated regulations help neither the adopters nor the enforcers.

Existence Proof (true and tried technologies)

- TPC and DFS are already mandated in Europe and Japan (e.g. ETSI HIPERLAN/2)
- LBT-CWT is an abstraction of widely successful CSMA/CA

Easy to Implement

- TPC, DFS, LBT-CWT are based on RSSI measurement that can be obtained from a variety of modulation schemes

Mapping Proposal to Goals

Goal 1: Allow innovations in PHY and MAC

- DFS, TPC allow CDMA, TDMA, FDMA, CSMA etc. protocols over most of the band

Goal 2: Prevent mutual interference between transmitters

- DFS and LBT-CWT

Goal 3: Last one in can still use the spectrum

- LBT-CWT provides probabilistic fairness. Greedy transmitters are not allowed to monopolize channel

Goal 4: Maximize overall spectrum utilization and capacity

- DFS provides 100% utilization,
- LBT-CWT provides approximately 95% utilization
- Allow transmitters to transmit in the presence of existing signals

Notable Points

Interference redefined

In case a signal is detected, the device may still begin using the channel if its transmissions do not cause harmful interference to the current transmitting system.

Parameter values

- Chosen to make it easy for hardware vendors to incorporate and adopt rules
- For LBT-CWT, utilization goes over 95% when more than one device is on the network
- Provided in the paper…..

Open Questions

- All three rules can suffer from the hidden terminal problem
  - When receivers can transmit, hidden terminal problem can be removed
- Developing an algorithm for TPC without receivers in the loop is difficult

Conclusions

- Additional unlicensed band is needed to meet future demands on wireless data networks
- Regulation of this unlicensed band is necessary
- We have proposed an etiquette that includes TPC, DFS, and LBT-CWT
- Strengths
  - Simple for adopters and enforcers
  - Built on proven technology
  - Allows continued innovation in PHY and MAC
  - Does not dictate any particular network architecture
  - Improves definition of what constitutes interference
- Weakness
  - Does not solve hidden terminal problems
  - LBT-CWT does not get us 100% utilization
  - TPC needs to be defined b

Thanks !

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