Coupling QoS Provision with Interference Reporting in WLAN Sharing Communities

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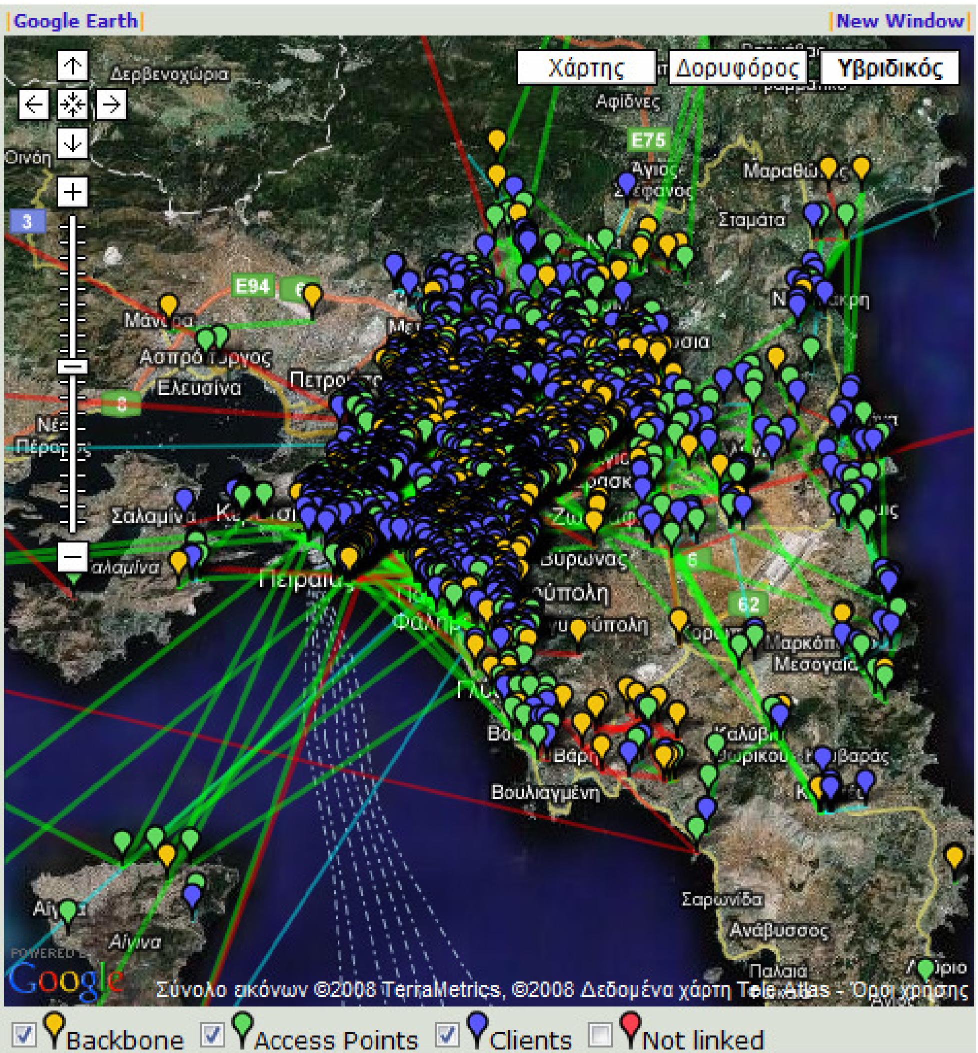
Motivation

- Continuous Wi-Fi deployment
  - Ease of installation
  - Operation in unlicensed bands
  - Unplanned, anarchic
- Full Wi-Fi coverage in metropolitan areas, but…
  - …most are secured using WEP, WPA, etc.
  - Need incentives to share one's WLAN with strangers
- Interference issues…
  - …due to unplanned deployment
  - IEEE 802.11b/g: only 3 non-interfering, non-overlapping channels
    - WLAN cells
  - Residential WLANs often operate on default channel settings
- Need solutions to the above problems
  - How about tackling them jointly?

WCNs

Seattle Wireless	Seattle, US	75 nodes	Mesh
AWMN	Athens, GR	2331 nodes	Mesh
CUWiN	Urbana, US	48 nodes	Mesh
Berlin's Freifunk	Berlin, DE	316 nodes	Mesh
NYCWireless	NYC, US	149 nodes	Hotspot-based
Wireless Philadelphia	Philadelphia, US	15 miles^2	Hotspot-based
FON	Worldwide	~210 000 registered APs	Hotspot-based

Athens Wireless Metropolitan Network



- **among the largest, globally**
  - **2331 active nodes**
  - **2786 links**
  - **791 active services**
- **Node #66 @ MMlab**

Background

- Sharing Wi-Fi P2P-style
  - Reciprocal Wi-Fi sharing: Open one's WLAN to roaming users to have the same benefit when mobile
- Client-assisted interference mitigation
  - Use client feedback to decide on optimal WLAN configuration
  - Can reveal *hidden interference* due to hidden terminals

Peer-to-Peer Wi-Fi Sharing

- P2P Wireless Network Confederation (P2PWNC)*
  - A WLAN sharing community
- Rely on reciprocity
  - Users set up their APs for public access
  - Get access to other peers' APs when mobile
  - Access opportunities and QoS proportional to their contribution
- No central authorities
  - Users identified by self-certified public-private key pairs
- Accounting based on the exchange of digital "receipts"
  - Receipt: proof of transaction signed by client
  - Distributed accounting: each peer stores receipts
- Implementable on common WLAN equipment
  - Linux-based AP, Smartphones, PDAs

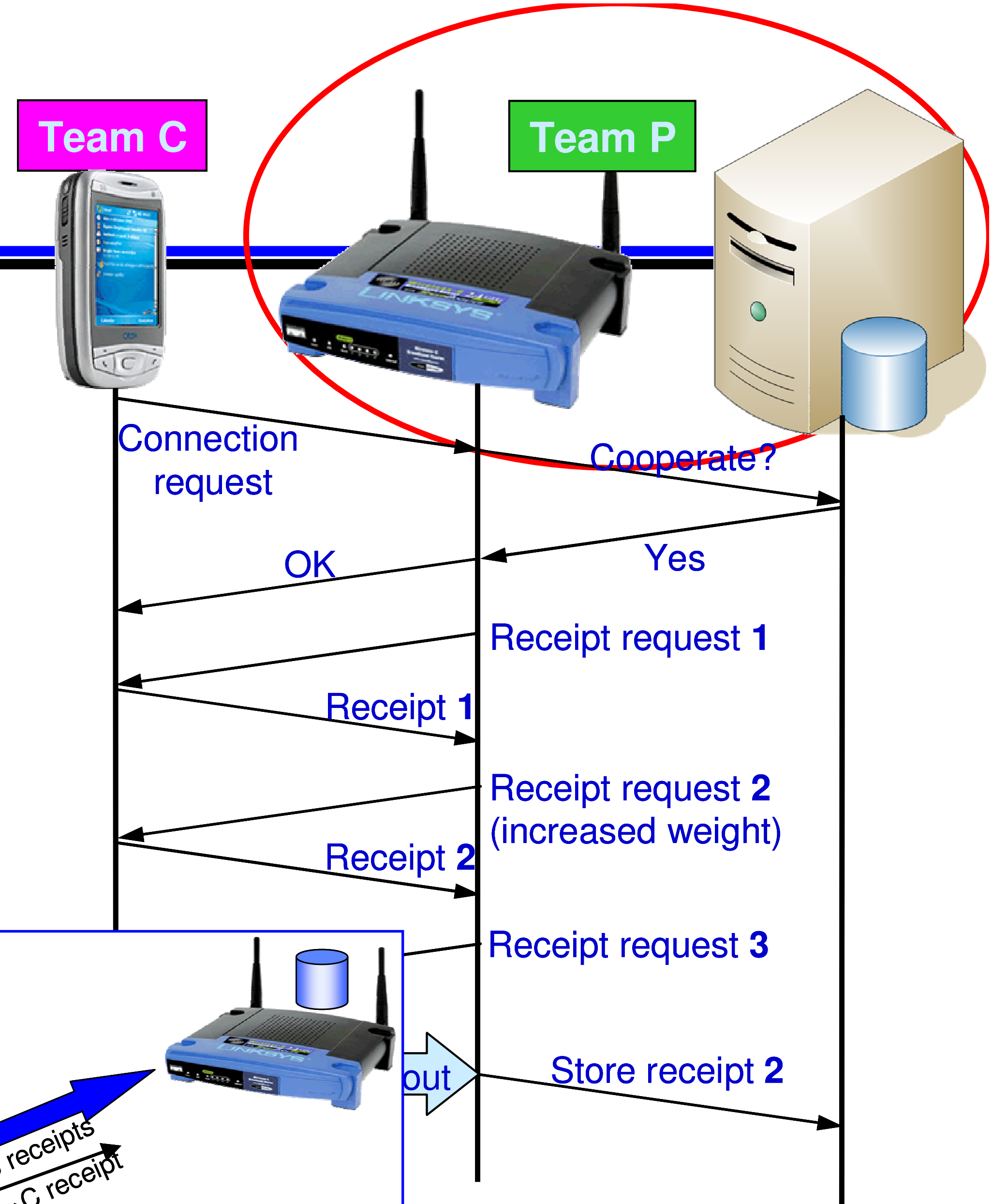
* E. C. Efstathiou, P. A. Frangoudis, and G. C. Polyzos, Stimulating Participation in Wireless Community Networks, IEEE INFOCOM 2006, Barcelona, Spain, April 2006.

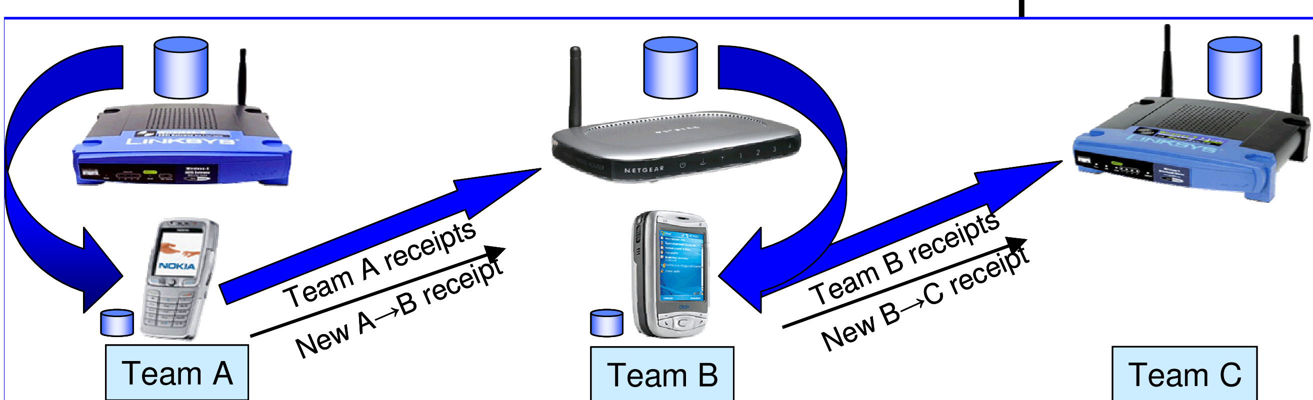
P2PWNC Receipts & Gossiping

P2PWNC receipts

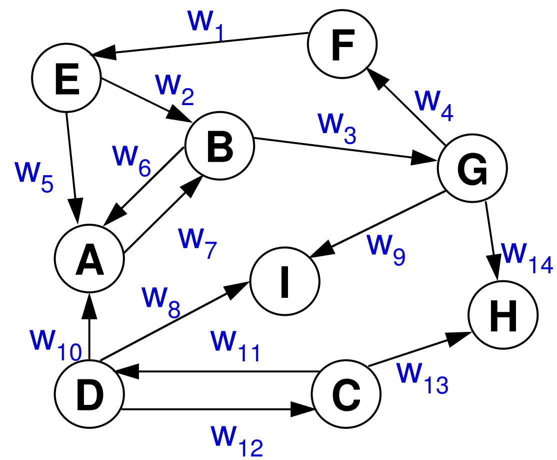
- Proof of prior contribution

Provider public key
Consumer certificate
Timestamp
Weight (bytes)
Consumer signature





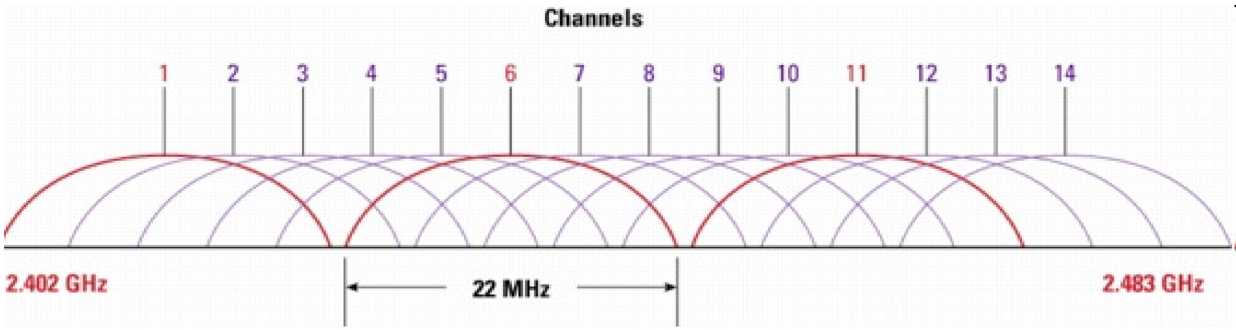
P2PWNC Reciprocity Algorithm



- Receipts form a weighted directed graph
  - Nodes: peers/peer IDs
  - Edges: receipts, “dept” between two peers
  - Represents the system’s history of transactions
- Reciprocity algorithm
  - Input: receipt graph, provider ID, consumer ID
  - Output: *Subjective Reputation Metric (SRM)*
  - Uses maximum flow techniques.
- Subjective Reputation Metric
  - How good a contributor the visitor is in the eyes of the provider
  - Probability that the visitor will be granted access

Dealing with Interference (1/2)

- IEEE 802.11 channels not truly orthogonal
  - 802.11b/g: 3 interference-free (non-overlapping) channels



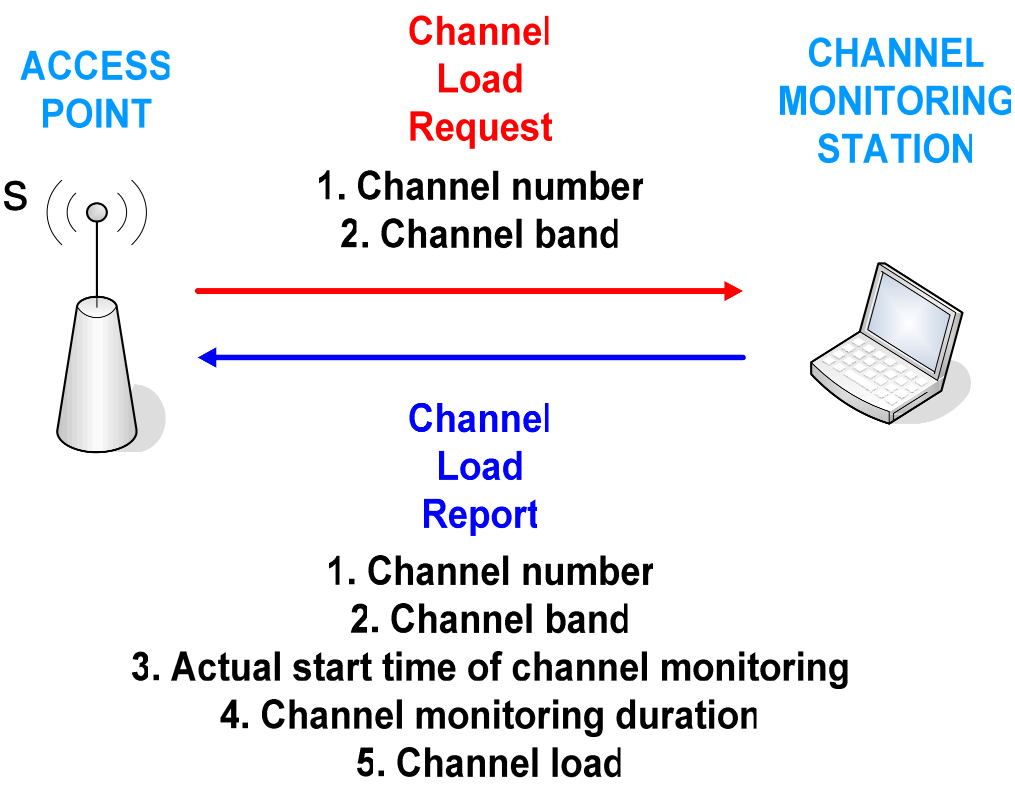
- Interference detection
  - AP-centric vs. client-based

- Interference mitigation
  - Channel selection, power control, directional antennas, ...
  - Outside the scope of this work

IEEE 802.11k: Radio Resource Measurements

- Specifies types of ***radio resource information*** to measure and the associated request and report mechanisms
  - Provides information to discover the best available access point
  - Load Balancing
  - Improve the way traffic is distributed within a network

Mangold & Berlemann: "IEEE 802.11k: Improving Confidence in Radio Resource Measurements," IEEE PIMRC 2005.



Dealing with Interference (2/2)

- AP-centric schemes
  - Sense spectrum usage at the AP site
  - Easier to control/manage
  - May require additional Wi-Fi interface (for channel monitoring)
  - Fail to capture interference beyond the AP (due to hidden terminals)
- Client-based schemes
  - Clients periodically monitor channel usage
  - Report to APs (or other control entity)
  - Reveal more information, capture user-perceived interference
  - Trustworthy reports?
  - Monitoring overhead?

Our Position

- Tackle public wireless access and interference mitigation jointly
  - P2PWNC for mobile Wi-Fi access
  - Client feedback about interference suffered

- Why should a P2PWNC client provide feedback about interference?
  - Offer QoS benefits in exchange

- Will it work?
  - Yes, if it has low overhead for the client
  - Otherwise: clients refuse to report, provide fake feedback

System Operation

- AP owners partition their Internet bandwidth
  - B_{owner}: reserved for personal use
  - B_{P2PWNC}: shared among P2PWNC visitors
  - B_{bonus}: bonus for interference reporting

- Visitor i gets access
  - P2PWNC protocol
  - Reciprocity algorithm → SRM_i

- Periodically, the AP requests for interference reports from each client
  - Client may (or may not!) perform a channel scan & report to the AP
  - Technologies
    - IEEE 802.11b/g active scan (channel, RSS, …)
    - Future: IEEE 802.11k
  - Client gets a QoS bonus for that

QoS as an incentive for interference reporting

- QoS extensions to the basic P2PWNC scheme
  - Clients get proportional bandwidth to their SRMs…
  - …plus a bonus for the amount of interference reports they provide

Portion of the bandwidth dedicated to P2PWNC users

- Assume an AP with n visitors. Visitor i gets:

$$B_i = \frac{SRM_i}{c + \sum^{n} SRM} B_{P2PWNC} + r_i \frac{B_{bonus}}{n}$$

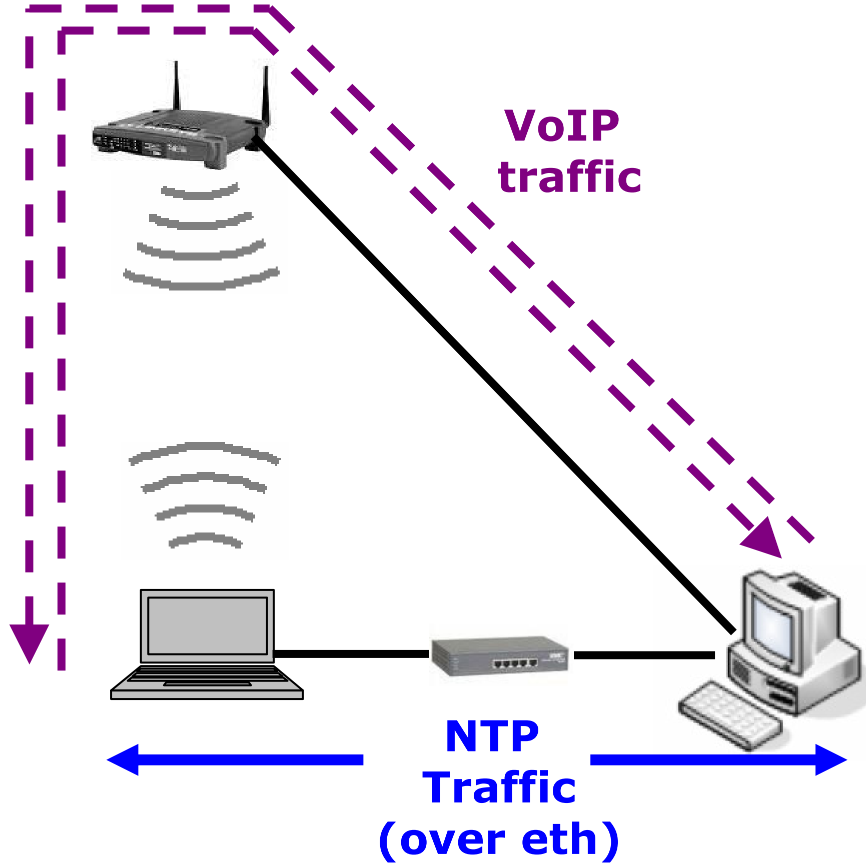
Portion of the bandwidth for rewarding interference reports

Performance overhead

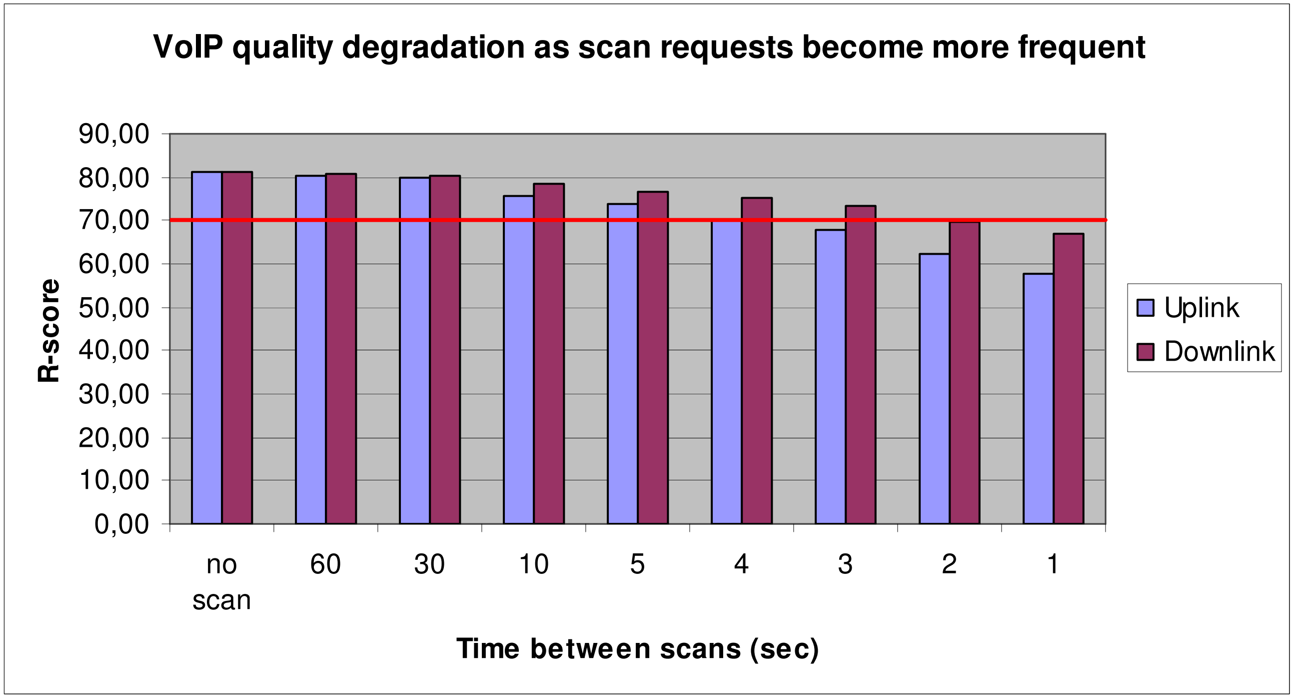
- Stations cannot receive/transmit app. packets while scanning
- Active scan on 11 channels: >250msec!
- Overhead depends on report request frequency
- Disincentive for clients to contribute reports?
  - No, if requests are not frequent and considering bandwidth bonus
- But how high is this overhead…
  - …especially for delay-sensitive apps?

Measuring the overhead…

- Purpose: measure VoIP performance degradation due to periodic scanning
  - Experiment with various request frequencies
- Traffic pattern
  - Bidirectional UDP/RTP traffic, 50 packets/sec, 20bytes payload (G.729)
- VoIP quality assessment
  - E-model (R-score/Mean Opinion Score)
  - Based on network-level per-packet measurements (delay, loss, jitter)
- Testbed
  - IEEE 802.11b @ 11Mbps, no RTS/CTS
  - Linksys WRT54GS AP
  - Intel PRO Wireless 2200 card, ipw2200 Linux driver
  - Sync using NTP (over eth interfaces)



Results



- Acceptable quality: R-score > 70
- Moderate scanning frequency (e.g. 2 scans/min) ➔ Minimal QoE degradation
- Negligible mean e2e delay
- Worse quality mainly due to jitter

Some Open Issues

- Security and reliability
  - How to spot fake reports?
    - Filter reports using a majority rule
    - Efficiency may depend on client distribution
  - Use a client reputation scheme, punish/reward?
  - Use monitors (Where to place them? How many? Who owns them?)

- Model and study incentives/QoS mechanism
  - Intuitively, no strong incentive to cheat…
  - …but, still, needs to be proven

- Smarter monitoring/reporting
  - Ask each client to scan a subset of the 11 channels
  - Will reduce scanning time

Conclusion

- Community-based WLAN access & interference mitigation can be jointly considered

- Client-based interference sensing/reporting has low overhead if performed moderately

- Network access & QoS rewards for interference reports, under two basic assumptions:
  - Wi-Fi operators value this information
  - No significant overhead for clients

- Many issues need further study

Thanks!

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