Optimizing the Channel Load Reporting Process in IEEE 802.11k-enabled WLANs

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IEEE 802.11k: Radio Resource Measurements

- Specifies types of ***radio resource information*** to measure and the associated request and report mechanisms

- Provide information to discover the best available access point

- Load Balancing
  - If the access point having the strongest signal is overloaded, a wireless client is connected to one of the access points with ***lower utilization***

- Improve the way traffic is distributed within a network

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

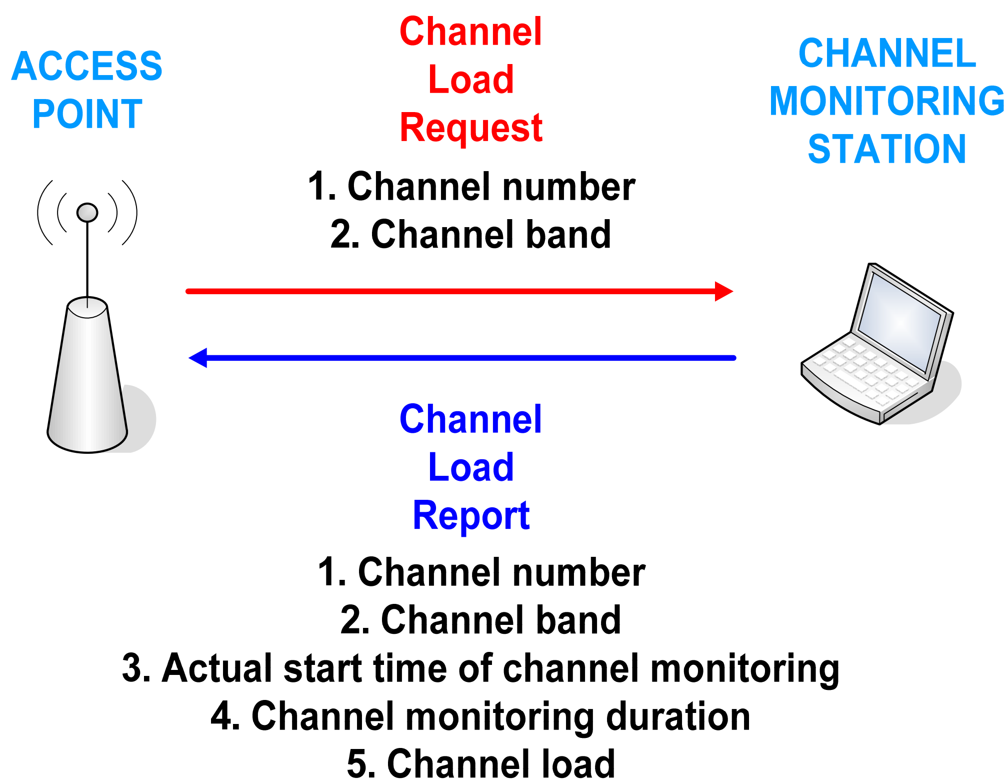
The Process of Monitoring

- ***Channel monitoring station*** reports estimated channel load
  - number (ID) of monitored channel
  - frequency band of monitored channel
  - actual start time of monitoring & monitoring duration
  - estimation of channel load:
    - final computed confidence interval
    - (final estimated mean load)

  For example:

  [0.13, 0.25] confidence interval indicates ***channel load*** between 13% & 25% w. prob. *p*=0.95

  and mean estimated load 19%

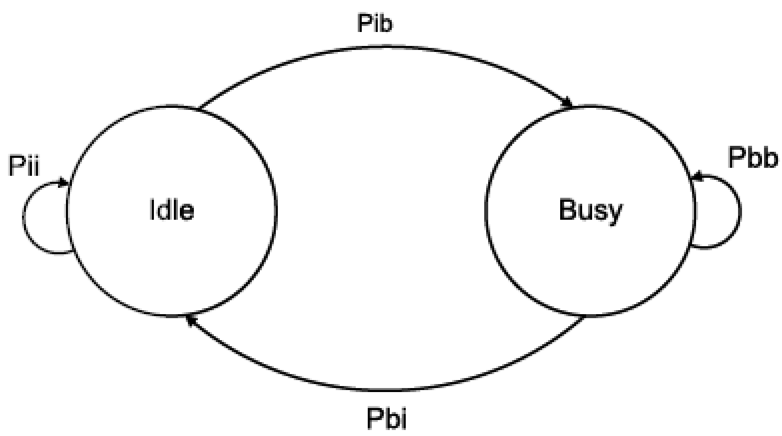


More General Motivation

- Open/Dynamic Spectrum Access

  Cognitive Radio Networks
- Need reports of the channel state as it is sensed…
  - over time
  - across the area (as sensors cover/pass through it)
    - building coverage maps
- Reporting devices
  - may be ad hoc, dedicated devices (sensors)
  - or regular clients (most probably)
  - In both cases: need efficient/economic sensing/sampling
    - continuous / regular reporting
    - energy / battery issues
    - impact on main client function

Channel Pattern Generation



- Simulation of the wireless channel utilization using the Gilbert model
  - Idle channel → state 0
  - Busy channel → state 1
- ***slot duration*** = 0.02 ms

  (IEEE 802.11b)

- During a ***channel monitoring sub-period***, a channel monitoring station is taking samples from the channel
- Present a simple algorithm for performing the ***channel monitoring process*** based on the concept of confidence intervals
- sampling period determined by the quality of channel monitoring station
  - ***High quality/high cost*** stations: samples with r = ½ ms
  - ***Low quality/low cost*** stations: samples with r = ¼ ms

The Algorithm: Channel Load Measurement

- ***if*** a channel load report is requested
  - ***while*** monitoring the channel do
  - ***for*** the next period equal to ***channel monitoring sub-period***
    1. sample the channel with ***rate r***
    2. calculate the confidence interval and the estimated mean value of all taken samples
    3. ***if*** the width of last computed confidence interval $w_{current}$, is smaller than a default value, let it be $w_{default}$

       or the improvement ratio value is smaller than a minimum ratio, let it be $improvement_{min}$
       - terminate monitoring process
       - report the results of channel monitoring process to the requesting entity
       - wait for a new reporting request
       - ***else*** continue monitoring

Scenarios

- WLAN cell where wireless clients (1, 5, 15, 25) are attached to an AP connected to a wired host
  - Each wireless node transfers data using **FTP** to the wired host, via the AP
  - Each wireless client sets up a **VoIP** session with the wired host (CBR carried over UDP)
  - Each wireless client simultaneously executes **both** the **FTP** and **VoIP** applications

Gilbert Model Parameters

GILBERT PARAMETERS FOR FTP TRAFFIC

Number of nodes	P_b	P_i	P_{ib}	P_{bi}
1	0.795	0.205	0.103	0.027
5	0.805	0.195	0.091	0.022
15	0.814	0.186	0.094	0.021
25	0.815	0.185	0.094	0.021

GILBERT PARAMETERS FOR VOIP TRAFFIC

Number of nodes	P_b	P_i	P_{ib}	P_{bi}
1	0.364	0.636	0.021	0.036
5	0.841	0.159	0.160	0.030
15	0.873	0.127	0.197	0.029
25	0.882	0.118	0.212	0.028

GILBERT PARAMETERS FOR FTP AND VOIP TRAFFIC

Number of nodes	P_b	P_i	P_{ib}	P_{bi}
1	0.782	0.218	0.112	0.031
5	0.841	0.159	0.159	0.030
15	0.873	0.127	0.198	0.029
25	0.883	0.117	0.213	0.028

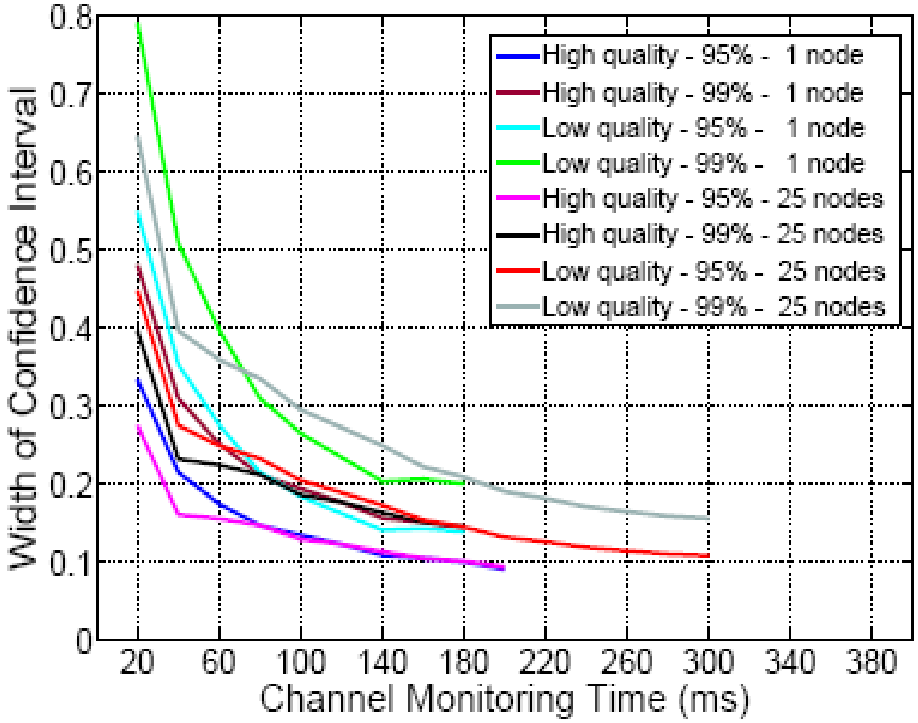
Experimentation

- We have implemented our channel monitoring algorithm in ***Matlab***
- simulated its operation on various channel access patterns that we derived using the Gilbert model
- We examine the change in the width of the computed confidence intervals as a function of the channel monitoring duration
- ***Channel monitoring sub-period*** = 20 ms

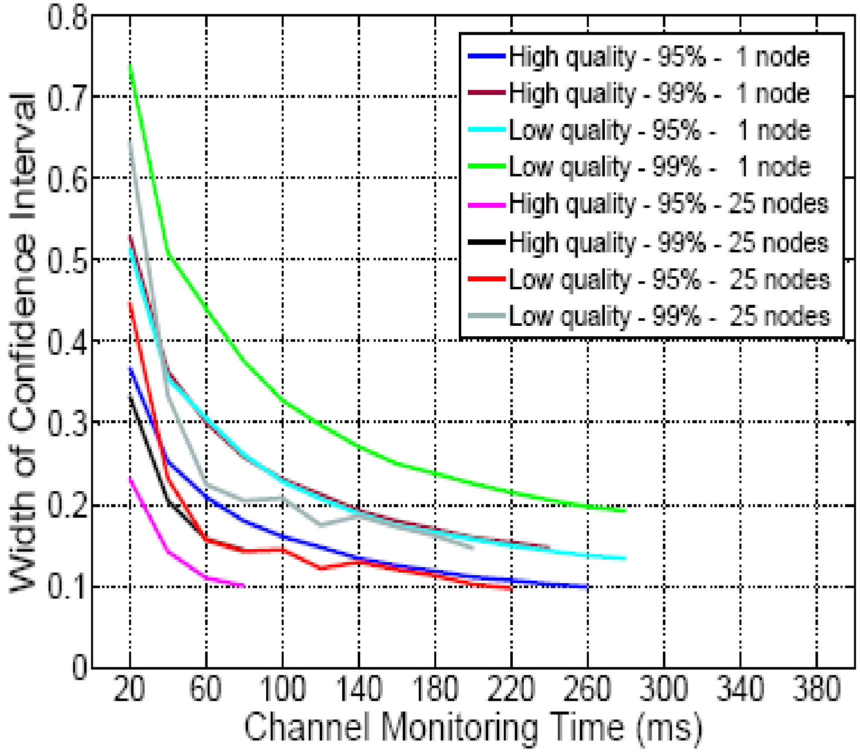
  → after this value the channel monitoring duration is increased without significant enhancement in results

Results – FTP, VoIP

- FTP

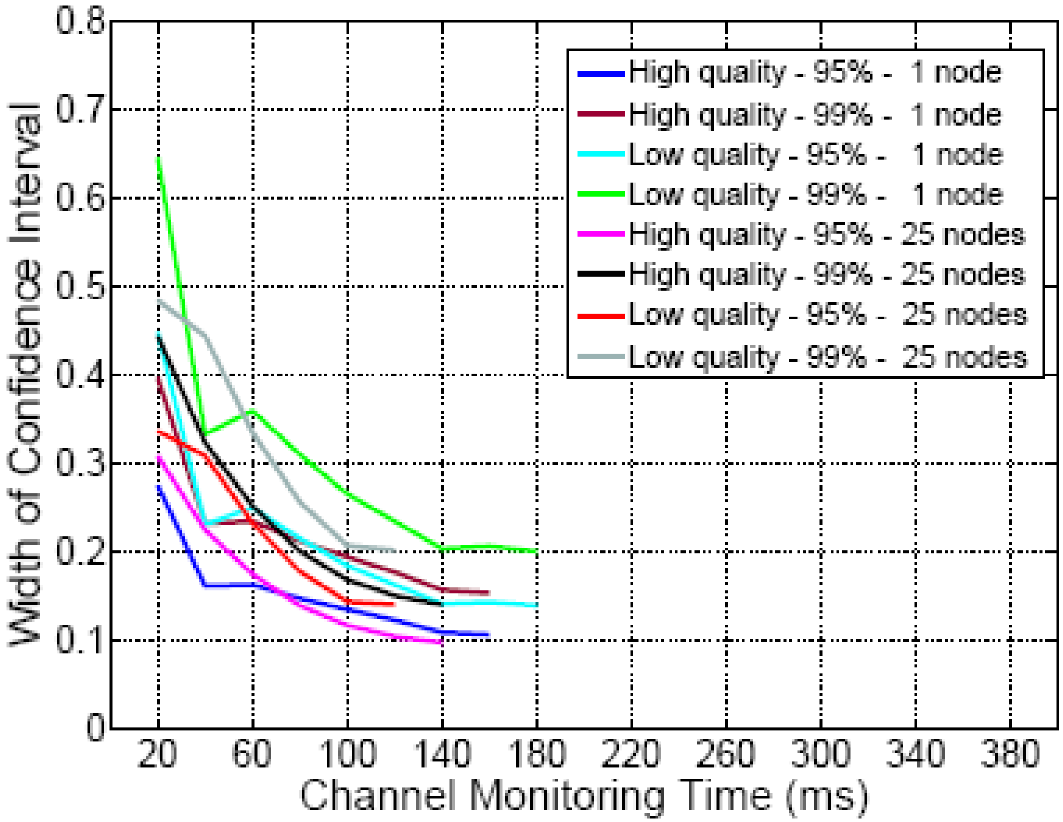


- VoIP



Results – FTP & VoIP

- FTP & VoIP concurrently



Evaluation Tables

- FTP

Monit. Station Quality	Conf. Lev. (%)	Numb. of nodes	Confidence Interval (%)	Mean Load (%)	True Load (%)	Total Time
High	95	1	77.41 - 86.59	82.00	79.15	200
High	99	1	72.76 - 87.24	80.00	78.79	180
Low	95	1	74.12 - 88.10	81.11	78.79	180
Low	99	1	71.06 - 91.16	81.11	78.79	180
High	95	25	75.77 - 85.23	80.50	81.73	200
High	99	25	72.13 - 86.76	79.44	81.76	180
Low	95	25	75.22 - 86.11	80.67	82.64	300
Low	99	25	72.83 - 88.51	80.67	82.64	300

- VoIP

Monit. Station Quality	Conf. Lev. (%)	Numb. of nodes	Confidence Interval (%)	Mean Load (%)	True Load (%)	Total Time
High	95	1	28.15 - 38.00	33.08	38.20	260
High	99	1	24.77 - 39.40	32.08	37.60	240
Low	95	1	25.47 - 38.81	32.14	38.36	280
Low	99	1	22.54 - 41.74	32.14	38.36	280
High	95	25	87.51 - 97.49	92.50	88.52	80
High	99	25	85.32 - 99.68	92.50	88.52	80
Low	95	25	85.16 - 94.84	90.00	89.04	220
Low	99	25	82.69 - 97.31	90.00	89.14	200

Evaluation Tables

- FTP & VoIP concurrently

Monit. Station Quality	Conf. Lev. (%)	Numb. of nodes	Confidence Interval (%)	Mean Load (%)	True Load (%)	Total Time
High	95	1	74.66 - 85.34	80.00	77.12	160
High	99	1	72.31 - 97.69	80.00	77.12	160
Low	95	1	74.12 - 88.10	81.11	77.10	180
Low	99	1	71.06 - 91.16	81.11	77.10	180
High	95	25	81.54 - 91.32	86.43	86.06	140
High	99	25	79.39 - 93.47	86.43	86.06	140
Low	95	25	81.30 - 95.37	88.33	85.91	120
Low	99	25	78.21 - 98.46	88.33	85.91	120

Summary & Conclusions

- We investigated the channel load reporting mechanism of the IEEE802.11k standard
- We propose a mechanism to monitor a wireless channel and report an accurate estimate of the channel's load with minimum monitoring cost
- We reduce the
  - *channel monitoring duration*
  - confidence interval calculation overhead
- We performed simulations of realistic WLAN application scenarios to determine the Gilbert model's parameters

Thanks!

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