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Wireless LANs

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| HEW Evaluation Methodology | | | | | |
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This document describes the simulation methodology, evaluation metrics and traffic models for assessing HEW proposals’ performance.

**Simulation Methodologies - General Concept**

Three tools are defined to enable the assessment of proposed HEW techniques performance and gain relative to 11ac, each having its own advantages:

1. PER simulations – typically used for new PHY features for assessing point to point performance
2. PHY System simulations – provide system-wise (multi-BSS) performance assessment with emphasis on PHY abstraction accuracy and very simplified MAC
3. MAC System simulations - provides system-wise (multi-BSS) performance assessment with emphasis on MAC accuracy and very simplified PHY

Both PHY and MAC system simulations are proposed as tools in order to:

1. Simplify some of the MAC/PHY details respectively
2. Speed up development (by reducing dependency of PHY on MAC and vice versa)
3. Improve insight into the specific reason for performance gains/losses (which is more difficult to assess in multi-STA multi-BSS environments that include all possible PHY and MAC details).
   * PHY system simulations are expected to provide higher throughput since some MAC protocol inefficiencies are excluded
   * PHY system simulations can better explore different PHY features
4. Some proposed techniques may not require all PHY/MAC details in order to evaluate gains

PHY/MAC system simulations are used over the same simulation scenarios as defined in [10][11]

**System Simulation - General Description**

A system simulation is comprised of multiple drops and multiple transmission events.

A drop is defined by a known AP and STA locations. Different drops have different STA locations and possibly different AP locations as defined by the simulation scenario document [11].

During a transmission event a set of transmissions occur across multiple BSS. Multiple transmission events with typical aggregate duration 1-10[sec] beyond a warm-up time are required to assess performance of a given set of APs and STAs configuration. Each BSS may have different start time, duration and end time for its transmission event but time alignment (start, duration, end) of transmission events across different BSS in the system is a possible outcome of a proposed MAC protocol.

A’warm-up’ period may be used to allow for some parameters to converge. For example:

1. MCS selection - if the MCS adaptation algorithm requires decisions based on past performance then the warm-up period shall be used for initializing the algorithm.

1. Offered load - if all flows start exactly at T0, then the offered load goes from 0 to X instantaneously, and high amount of collisions will occur for a large amount of STA in the scenario. It will take a warm-up time to recover.
   * The backoff mechanism will effectively reduce the total offered load by increasing CW at nodes, until the offered load is at Y < X

General simulation structure:

For drop=1:N {

Drop APs and STAs according to description in [11]

Associate STAs with APs according to description in [11]

For transmission event=1:M {

* + Note - For MAC simulations, one can count time, ensuring that enough time has passed to see M transmission events
  + Note – the transmission event duration may not be the same in each BSS
  + Generate traffic at chosen nodes. Nodes chosen in compliance with
    - CCA rules and various other EDCA parameters
    - Channel access ordering rules (round robin, proportional fair, distributed access)
  + Generate packets consistent with link adaptation algorithm
    - SU OL, SU BF, MU
    - MCS selection
  + Perform transmissions
  + Determine packet success or no
  + Collect metrics.

}

}

**Simulation Methodology I - PER Simulation**

PHY PER simulations are used to verify point to point performance or aspects that need this type of simulation, especially new PHY features or preamble performance.

PHY impairments such as PA non-linearity, phase noise, synchronization error, channel estimation error, non-linear receivers are more readily incorporated into PER simulations and may be needed if some techniques are adversely affected by those impairments [6][9].

Other impairments such as the impact of OBSS interference or inter-symbol interference should also be verified by PER simulations by explicitly adding interfering packets to the simulation.

**Simulation Methodology II - PHY System Simulation**

The emphasis here is on accurate modeling of the PHY using PHY abstraction (see description in the Appendix) with focus on DATA packets.

Only the very basic MAC as defined in 11ac is simulated. This is captured in the following description of a PHY system simulation using the approach taken in 11ac [17]:

1. Randomly allow an AP or client to transmit, consistent with CCA rules (meaning some devices will not be able to transmit in parallel). CCA rules may assume an RTS-CTS exchange preceding the DATA transmission.
2. Allow additional AP and STAs to transmit in parallel until every STA has CCA busy
   1. This assumes full buffer traffic. Other traffic models may be simulated.
3. Calculate SINR at each receiver and map to packet fail/pass
4. Repeat for multiple transmission events
5. Repeat for multiple drops

An implicit assumption is made that transmissions in OBSS are time synchronized since devices hear the preamble and defer for the duration of a packet. However, packet transmission length in different OBSS may not be identical.

Other MAC proposals can be introduced by similarly modifying the description above to include only the salient features.

PHY parameters that need to be defined per AP and per STA:

1. Transmission BW
   * If transmissions in different BSS occupy adjacent RF carriers (or different BW) adjacent channel interference should be modeled
2. Number of antennas (could be different for different STA)
3. Transmission scheme- SU OL, SU BF, MU (realistic feedback accuracy and overhead should be modeled but explicitly simulating channel feedback may not be required)
4. Channel model (multipath fading, Doppler, path and penetration losses, shadowing)
5. Transmission power as defined in [11]

Link adaptation needs to be described as well –

1. MCS choice – for simplicity propose to use as baseline fixed MCS per link (the MCS can be chosen based on the SNR with some fixed delta to accommodate interference).
   * Slow adaptation of the baseline MCS choice using previous error rate statistics can be modeled
   * Usage of genie MCS could be used to assess upper performance bound but not realistic performance.
2. Transmission mode selection SU OL vs. BF vs. MU should be described (transmission mode can be fixed or dynamic).

**Simulation Methodology III - MAC System Simulation**

The emphasis here is on accurate representation of the MAC and traffic models.

The PHY parameters can be simplified to a SISO configuration running over AWGN - path and penetration loss should be modeled according to the scenario-specific definition.

MAC parameters that need to be described:

1. Use of beacon and management frames
2. Aggregation policy
3. Usage of RTS-CTS or CTS2SELF
4. EDCA parameters (AC, CWmin, CWmax, AIFSN)
5. CSMA backoff procedures, energy and preamble detection
6. Basic rate set

If other MAC schemes are proposed they need to be described (e.g. RAW as defined in 11ah or HCCA)

Link adaptation needs to be described –

MCS choice – for simplicity propose to use as baseline fixed MCS per link (the MCS can be chosen based on the SNR with some fixed delta to accommodate interference).

* + Slow adaptation of the baseline MCS choice using previous error rate statistics can be modeled
  + Usage of genie MCS could be used to assess upper performance bound but not realistic performance.

**Simulation Methodology Choice**

Proponents of different techniques should provide justification for their proposed simulation methodology used to justify the technique’s gains. Proponents should also provide a comparison to performance with baseline parameters, e.g. .11ac.

Examples:

* PHY PER simulation:
  1. New PHY – a PER simulation is typically sufficient in order to decide the number of pilots, interleaver parameters and other parameters.
  2. Preamble performance
  3. Implementation losses of current and new PHY modes.
  4. Interference, especially if varying across the packet, impact on PER.
* PHY System simulation:
  1. Impact of number of antennas on multi-BSS performance
  2. Impact of PHY techniques in the context of multi-BSS
  3. Impact of frequency re-use in multi-BSS
  4. Impact of CCA levels on system throughput
* MAC System simulation:
  1. Impact of MAC scheduler – for example EDCA vs. RAW (as in 11ah) vs. HCCA vs. other techniques
  2. Impact of frequency re-use in multi-BSS
  3. Impact of CCA levels

Note that although some parameters/techniques are shown as common to both PHY and MAC system simulations, each of them can focus on modeling more accurately the PHY and MAC details respectively and the outcome can be compared for improved insight.

Note also that some techniques may require both accurate MAC and PHY details to be simulated in which case the detailed PHY abstraction should be added to the MAC system simulation.

**Traffic Models**

Full buffer model is baseline – users always have DATA to send and receive.

A more realistic FTP traffic model may be used based on [15]. Specifc parameters are TBD.

A mix of small and large packets should be evaluated in order to test realistic assumptions on system performance.

In addition, specific traffic models for Video [16] are TBD.

**Metrics**

For PER simulations the typical metric is dB gain/loss in waterfall curves. The operating range to be observed is 1% to 10% PER.

For system simulations we propose to look at several metrics [2]-[9]:

* + Aggregate area throughput [bps/m2] for specified scenarios - this metric directly relates to the average throughput per BSS and can be used to compare different deployment densities and heterogeneous deployments. For example:
    - How is area throughput impacted as a function of inter AP distance and number of STA?
    - How is area throughput impacted with flat deployments vs. heterogeneous?
  + Average per-STA throughput in all participating BSS
  + 5% point in the throughput CDF curve – this metric measures cell edge performance
  + More information may be provided such as the entire CDF curve and MCS histogram [3]
  + Time constraint throughput for delay sensitive applications

Higher layer QoS metrics [4] are TBD.

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**Appendix - PHY Abstraction**

The objective of PHY abstraction is to accurately predict PER simulation results in a computationally efficient way to enable running system simulations in a timely manner.

The underlying principle is to calculate an effective average SINR (*SINReff* ) in a given OFDM symbol. This quantity then acts as a link between AWGN PER and multipath channel PER for a given coding type, block size and MCS level.

Effective SINR (*SINReff* ) is typically calculated as follows



where *SINRn* is the post processing SINR at the *n*-th subcarrier, *N* is the number of subcarriers in a coded block and Φ is a mapping function.

Several mapping functions can be used such as Constrained Capacity, EESM, MMIB, RBIR, etc. [12]

A general description is as follows:

* + Start from an agreed upon per-MCS required SNR in AWGN assuming 1000bytes SISO 10% PER point.
  + With one receive antenna:
    1. Compute SINR per tone – the ‘S’ term is a function of the Tx power and channel. The ‘I’ term is due to OBSS, intra-BSS interference or MU-MIMO related interference. Note that ‘I’ could vary during a packet due to shorter interfering packet than the desired packet or start of new interfering packet midway through the desired packet.
    2. Transform to MCS using one of several methods:
  + Constraint capacity - calculate the per-tone capacity log2(1+SINR), this could be constrained to 256QAM capacity, and average across all data tones used for transmission to arrive at the average capacity. From the average capacity derive the average SINR per tone and transform back to MCS using the AWGN MCS table.
  + MMIB - calculate the average per-bit capacity as described in [13]
  + RBIR - calculate the symbol information as described in [14].
* With multiple receive antennas:
  + 1. SINR should reflect the receive combining output from all antennas and the combining method should be indicated
    2. For MIMO reception, a linear MMSE receiver can be assumed (see description in section 4.4.4 of [12]) to be applied to the MIMO channel to generate an SINR per spatial stream.