EEE P802.11  
Wireless LANs

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| HEW SG Simulation Scenarios | | | | |
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# Abstract

This document describes the simulation scenarios for the HEW SG.

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# Revisions

|  |  |  |
| --- | --- | --- |
| **Revision** | **Comments** | **Date** |
| *R0* | Initial draft template | Aug 28th |
| *R1* |  | Sept 15th |
| *R2* | Made it consistent with document 1000r2 | Sept 16th |
| *R3* | Included Scenario 1 from 1081r0  Included Scenario 2 from 722r2  Included Scenario 3 and 4 from 1248r0; scenario 3 likely compatible with documents 722 and 1079.  Included concept from 1176r0  Added References  Updated co-authors | Oct 4th |
| *R4* | Minor corrections | Oct 4th |
| *R5* | Added description for scenario 4a (Simone (Qualcomm), Ron (Broadcom))  Tentative addition of contributions related to traffic models; more discussion is needed:   * Added video traffic models from #1335 (Guoqing Li, Intel) * Table for traffic models (Bill, Sony) * Management Traffic profile and % of unassociated users (Reza, Cisco) * Application activity intervals (Huai-Rong, Samsung)   Indicated that legacy STAs can be present (Various)  Indicated that legacy APs can be present in scenario 1(Liwen, Marvell)  Indication of antenna height (Wookbong, LG)  RTS Thresholds (Liwen, Marvell)  Primary channel location (Liwen (Marvell), Klaus (Nokia))  Clarified that all BSSs are either all at 2.4GHz, or all at 5GHz (Liwen, Marvell)  Some changes on traffic model for Residential Scenario (Klaus, Nokia)  Initial indications of channel model (various, Joseph, (InterDigital), Wookbong (LG); needs more discussion)  Clarification on non-HEW definition.  Other comments from Jason, David, Wookbong, Thomas | Nov 14th |
| *R6* | Modified the number of APs in scenario 2 (Filip (Ericsson))  Add description of the interference scenario for Scenario 2 (David (Huawei))  Added considerations on feedback from WFA |  |

# Notes on this version

This document consolidates contributions on scenarios details, from various authors.

This document reflects the comments/submissions received, but it is not a final version by any means and is subject to changes based on further discussion and feedback.

This document includes:

* scenarios classification based on the harmonization between  proposals in doc #1083r0 and 1000r2 that happened at the September meeting (also supported by the straw poll)
* Descriptions for scenarios 1 (from doc. #1081r0), scenario 2 (from doc. #722r2), scenarios 3 (from doc. #1248 and likely compatible with #722 and #1079), scenario 4 (from doc. #1248), scenario 4a (Ron), concepts from doc #1176; I believe the presence of ‘interfering scenarios’ in each scenario also satisfies the suggestions from #1114r1.
* traffic models specifications from 11-13/1305, 11-13/1334/5; several suggested changes received via email which do not have a doc # (see revisions table comments)

Major TBDs

* Traffic models
  + initial contributions received regarding video and management traffic models (DCN#1335, Reza), defining a traffic profile per scenario (#1305), applications activity time #1406 (Huai-Rong); also expecting contribution related to #1407 (Chao-Chun) regarding transport layer modelling.
  + This topic needs more work
    - I suggest to work toward a possibly unified/simplified abstraction model for the traffic definitions, then we can describe per each scenario how those traffic models apply to each STA; Also need to identify what goes in SS and what goes in EM
* Calibration scenarios;
  + More discussion is needed, Discussion so far indicated there are different options
    - Define a new scenario for calibration only
    - Define a calibration scenario per each ‘full’ scenario
      * May be a simplified version of the ‘full’ one
    - Use the scenario directly for calibration, using the default parameters
  + Doc #1392 indicates that calibration is important. I call for submissions for calibration scenarios description.
* Channel models per scenario
  + Not clear agreement on which channel models to be used in each scenario; some tentative included in the document
* Penetration losses
* Some other topics under discussion refer to simulation methodology/parameters that can be common and fixed across all scenarios, hence they may be directly included in the Evaluation Methodology document or in an appendix of this documents
  + Rate adaptation model
  + Use of wrap around for scenarios 3 and 4?
    - Discussion is needed; Use of wrap around with CSMA may create artefacts
  + Is the ‘random’ position of STAs randomly generated by each simulation run, or are we going to have a file with common positions?
  + Several channel model and RF related parameters that are likely to be common and fixed across scenarios see #1383

# Introduction

This document defines simulation scenarios to be used for

* Evaluation of performance of features proposed in HEW
* Generation of results for simulators calibration purpose.

Each scenario is defined by specifying

* Topology: AP/STAs positions, P2P STAs pair positions, obstructions , layout, propagation model
* Traffic model
  + STA - AP traffic
  + P2P traffic (tethering, Soft-APs, TDLS)
  + ‘Idle’ devices (generating management traffic such as probes/beacons)
* List of PHY, MAC, Management parameters
  + We may want to fix the value of some parameters to limit the degrees of freedom, and for calibration
  + Optionally, some STAs may use legacy (11n/ac) operation parameters, if required to prove effectiveness of selected HEW solutions
* An interfering scenario (its performance optionally tracked)
  + Not managed or managed by a different entity than the one of the main scenario
  + Defined by its own Topology, Traffic model and parameters

Per each of above items, the scenario description defines a detailed list of parameters and corresponding values.

Values included in curly brackets {} are mandatory and shall be adopted for any simulation.

Values included in square brackets [] are default values and they may be changed for simulations for performance evaluation; in case they are changed, the simulation results shall be accompanied by a list of the parameters and the corresponding values used in the simulation.

# Scenarios summary

This document includes a description for the following scenarios, according to document 11-13/1000r2.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Scenario Name** | **Topology** | **Management** | **Channel Model** | **Homogeneity** | **~Traffic Model** |
| **1** | Residential | A - Apartment building  e.g. ~10m x 10m apartments in a multi-floor building  ~10s of STAs/AP, P2P pairs | Unmanaged | Indoor | Flat | Home |
| **2** | Enterprise | B - Dense small BSSs with clusters  e.g. ~10-20m inter AP distance,  ~100s of STAs/AP, P2P pairs | Managed | Indoor | Flat | Enterprise |
| **3** | Indoor Small BSS Hotspot | C - Dense small BSSs, uniform  e.g. ~10-20m inter AP distance  ~100s of STAs/AP, P2P pairs | Mobile |
| **4** | Outdoor Large BSS Hotspot | D - Large BSSs, uniform  e.g. 100-200m inter AP distance  ~100s of STAs/AP, P2P pairs | Managed | Outdoor | Flat | Mobile |
| **4a** | Outdoor Large BSS Hotspot  + Residential | D+A | Managed + Unmanaged | Hierarchical | Mobile + Home |

## Considerations on the feedback from WFA

Document 11-13/1443 includes feedback from WFA regarding prioritization of usage models.

Document 11-13/1456r1 shows a mapping between the prioritized usage models and the simulation scenarios in this document (as of r5).

The summary is copied here:

* **Mapping**
  + 1b Airport / train station 🡪 Scenario 3
  + 1e E-education 🡪 Scenario 2
  + 3a Dense apartment building 🡪 Scenario 1
  + 4b Pico-cell street deployment 🡪 Scenario 4
  + 2b Public transportation 🡪 ??
    - No good match with existing scenarios
* **Is usage model 2b relevant for HEW, in the opinion of the SG?**
  + Usage model 2b is essentially ‘single cell’, which is a departure from ‘Dense scenarios’ scope of HEW
    - High density of STAs but likely just 1 or few APs
  + Goal of simulation scenarios is to capture key issues, and for proof of solutions
  + If considered not relevant: our current simulation scenarios are enough
  + If considered relevant: we need to either add one more scenario, or fit it into an existing one (preferred)
    - E.g. can it fit as a special case of Scenario 2 or 3?

# 1 - Residential Scenario

(From documents 11-13/1081r0**,** 786)

|  |  |
| --- | --- |
| **Parameter** | **Value** |
|  | |
| **Topology** | |
| Figure 1 - Residential building layout | |
| Environment description | Multi-floor building   * 5 floors, 3 m height in each floor * 2x10 rooms in each floor * Apartment size:10m x 10m x 3m |
| APs location | In each apartment, place AP in random xy-locations (uniform distribution) at z = 1.5 m above the floor level of the apartment. |
| AP Type | M APs in the building  AP\_1 to AP\_M1: HEW AP\_{M1+1} to AP\_M: non-HEW (M = Number of Apartments = 100, M1 = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz |
| STAs location | In each apartment, place STAs in random xy-locations (uniform distribution) at z = 1.5m above the floor level of the apartment, at a minimum distance TBD from the AP |
| Number of STA  and STAs type | N STAs in each apartment.  STA\_1 to STA\_N1: HEW STA\_{N1 +1} to STA\_N: non-HEW (N = TBD, N1 = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz |
| Channel Model | Option 1.  AP-AP: TGac channel model B  AP-STA: TGac channel model B  STA-STA: TGac channel model B  Option 2.  ITU InH model w/3D  WINNERII /WINNER+ w/wo 3D |
| Penetration Losses | Option 1.  Wall 12dB, Floor 17 dB+4dB  Option 2.  12·NWall+17·NFloor [11-14/0116r1]  Option 3.  14.5· (NWall+NFloor)((NWall+NFloor+2)/(NWall+NFloor+1)-0.46) [11-14/0083r0]  Where NWall is the number of walls between two devices, and NFloor is the number of floors between them |
|  | |
| **PHY parameters** | |
| Center frequency and BW | All BSSs either all at 2.4GHz, or all at 5GHz  [20MHz BSS at 2.4GHz, or 80 MHz BSS at 5GHz] |
| MCS | [Up to MCS 9, BCC] |
| GI | [Long] |
| Data Preamble | [2.4GHz, 11n; 5GHz, 11ac] |
| STA TX power | [17]dBm |
| AP TX Power | [23]dBm |
| AP #of TX antennas | {2,4} |
| AP #of RX antennas | {2,4} |
| STA #of TX antennas | {1, 2} |
| STA #of RX antennas | {1, 2} |
|  | |
| **MAC parameters** | |
| Access protocol parameters | [EDCA with default parameters] |
| Primary channels | [Random assignment of 3 non overlapping channels] |
| Aggregation | [A-MPDU / max aggregation size / BA window size, No A-MSDU, with immediate BA] |
| Max # of retries | [Max retries: 4] |
| RTS/CTS Threshold | [TBD] |
| Association | X% of STAs in an apartment are associated to the AP in the apartment; 100-X% of the STAs are not associated |

**Traffic model**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (Per each apartment) - TBD** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| D1 | AP/STA1 | Buffered video streaming |  | 50Mbps | VI |
| … |  |  |  |  | VI |
| DN | AP/STA\_N | Buffered video streaming |  | 50Mbps | VI |
| **Uplink** | | | | | |
| U1 | STA1/AP |  |  | 1.5Mpbs |  |
|  |  |  |  |  |  |
| UN | STA\_N/AP |  |  | 1.5Mpbs |  |
| **P2P** | | | | | |
| P1 | STA\_{N1+1}/STA\_{N1+2} | Buffered video streaming |  | 10Mbps | VI |
|  |  |  |  |  |  |
|  | STA\_{N-1}/STA\_{N} | Buffered video streaming |  | 10Mbps |  |
| **Idle Management** | | | | | |
| M1 | AP1 | Beacon | TX | TBD |  |
| M2-M | All unassociated STAs | Probe Req |  | TBD |  |

# 2 – Enterprise Scenario

(From the Wireless Office scenario in 11/722r2)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | | |
|  | | | |
| **Topology** | | | |
| Figure 2 - BSSs within the building floor | | | |
|  | | | |
| Toplogy_dense.png  Figure 3 - STAs clusters (cubicle) and AP positions within a BSS    Figure 4 - STAs within a cluster | | | |
| Topology Description | Office floor configuration (see Figure 2 and Figure 3)   * 1. 8 offices (see Figure 2)   2. 64 cubicles per office (see Figure 3)   3. Each cubicle has 4 STAs (see Figure 4) | | |
| APs location | 4 APs per office  Installed on the ceiling at:  AP1: (x=5,y=5,z=3)  AP2: (x=15,y=5,z=3)  AP3: (x=5,y=15,z=3)  AP4: (x=15,y=15,z=3)  From the left-bottom of each office location. | | |
| AP Type | {HEW} | | |
| STAs location | Placed randomly in a cubicle (x,y,z=2)  STA1: laptop  STA2: monitor  STA3: smartphone or tablet  STA4: Hard disk  Keyboard/mouse (TBR) | | |
| Number of STAs  and STAs type | N STAs in each cubicle. STA\_1 to STA\_{N1}: HEW STA\_{N1+1} to STA\_{N} : non-HEW (N = TBD, N1 = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz | | |
| Channel Model | Option 1.  AP-AP: TGac channel model D  AP-STA: TGac channel model D  STA-STA: TGac channel model D  Option 2.  STA/STA: TGac channel model  B | | |
| Penetration Losses | 7 dB per wall | | |
|  | | | |
| **PHY parameters** | | | |
| Center frequency and BW | | All BSSs either all at 2.4GHz, or all at 5GHz  [20MHz BSS at 2.4GHz, 80 MHz BSS at 5GHz] | |
| MCS | | [Up to MCS 9, BCC] | |
| GI | | [Long] | |
| Data Preamble | | [2.4GHz, 11n; 5GHz, 11ac] | |
| STA TX power | | [21dBm] | |
| AP TX Power | | [24dBm] | |
| AP #of TX antennas | | {4} | |
| AP #of RX antennas | | {4} | |
| STA #of TX antennas | | {1, 2} | |
| STA #of RX antennas | | {1, 2} | |
| **Parameters for P2P (if different from above)** | | | |
| P2P STAs TX power | | [21dBm] | |
|  | | | |
| **MAC parameters** | | | |
| Access protocol parameters | | | [EDCA with default EDCA Parameters set] |
| Primary channels | | | Four 80 MHz channels (Ch1, Ch2, Ch3, Ch4)  Ch1: BSS1, BSS5  Ch2: BSS2, BSS6  Ch3: BSS3, BSS7  Ch4: BSS4, BSS8 |
| Aggregation | | | [A-MPDU / max aggregation size / BA window size, No A-MSDU, with immediate BA] |
| Max # of retries | | | [10] |
| RTS/CTS Threshold | | | [TBD] |
| Association | | | X% of STAs associate with the AP based on highest RSSI; 100-X% of STAs are not associated. |
| **Parameters for P2P (if different from above)** | | | |
| Primary channels | | | TBD |

**Traffic model**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (Per each cubicle)** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| D1 | AP/STA1 | Web browsing, Local file transfer | T1 |  | VI |
| D2 | AP/STA3 | Web browsing, Local file transfer | T3 |  | BE |
| **Uplink** | | | | | |
| U1 | STA1/AP | Web browsing, Local file transfer |  |  |  |
| U2 | STA3/AP | Web browsing, Local file transfer |  |  |  |
| **P2P** | | | | | |
| P1 | STA1/STA2 | Lightly compressed video |  |  |  |
| P2 | STA1/STA4 | Hard disk file transfer |  |  |  |
| **Idle / Management** | | | | | |
| M1 | AP | Beacon |  |  |  |
| M2 | STAs | Probes |  |  |  |

## Interfering scenario for scenario 2

All surveys and observations so far have led to the same conclusion that most enterprises in the world are made up of micro, small or medium sizes. The results of the surveys also indicate that small enterprises consist of a single BSS whereby medium enterprises consist of 2 to 4 BSSs. Hence, a mixed office scenario that contains multiple BSSs belonging to different ESSs is proposed. These ESSs are managed independently. (Reference: 14/0051r0).

**Interference models:**

Based on the mixed enterprise topology, three kinds of interferences are considered:

* Interference with unmanaged networks (P2P links).
* Interference between APs belonging to different managed ESS due to the presence of multiple operators (multiple small and medium enterprises).

Use the model of scenario 3 with the following differences.

1. Each office is managed by a different entity, as indicated in Figure 5, where each color represents a management entity (note that BSS1 and BSS2 have same management entity)

BSS3

BSS4

BSS2

BSS1

20 m

20 m

BSS7

BSS8

BSS6

BSS5

Figure 5- Scenario 2 with different management entities

1. A number of additional P2P STAs

|  |  |
| --- | --- |
| STAs location | P2P pair with STAs placed 0.5m apart.  The P2P pairs are placed in a random location within a BSS |
| Number of STAs  and STAs type | P2P STAs:  NP2P STAs in a BSS. STA\_{16N+1} to STA\_{16N+NP2P-MP2P}: HEW STA\_{16N+NP2P-MP2P+1} to STA\_{16N+NP2P}: non-HEW  (NP2P = TBD, MP2P = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz |

# 3 - Indoor Small BSSs Scenario

(From document 1248r0)

This scenario has the objective to capture the issues and be representative of real-world deployments with high density of APs and STAs that are highlighted by the first category of usage models described in [5]:

* In such environments, the infrastructure network (ESS) is planned. For simulation complexity simplifications, a hexagonal BSS layout is considered with a frequency reuse pattern.
* In such environments, the “traffic condition” described in the usage model document mentions:
  + interference between APs belonging to the same managed ESS due to high density deployment: *this OBSS interference is captured in this scenario*
    - *note that this OBSS interference is touching STAs in high SNR conditions (close to their serving APs, while in outdoor large BSS scenario, the OBSS interference will be touching STAs in low SNR conditions (for from their serving APs)*
  + Interference with unmanaged networks (P2P links): *this OBSS interference is captured in this scenario by the definition of interfering networks, defined here as random unmanaged short-range P2P links, representative of Soft APs and tethering*
  + Interference with unmanaged stand-alone APs: *this OBSS interference is currently not captured in this scenario, but in the hierarchical indoor/outdoor scenario*
  + Interference between APs belonging to different managed ESS due to the presence of multiple operators: *this OBSS interference is currently not captured in this scenario, but in the outdoor large BSS scenario*
* Other important real-world conditions representative of such environments are captured in this scenario, [20]:
  + Existence of unassociated clients, with regular probe request broadcasts.

Different frequency reuse pattern can be defined (1, 3 and/or more).

Frequency reuse 3 is more realistic in a scenario with such high density of AP and we should use it as the default setting.

It is representative of the majority of planned deployments which apply frequency reuse higher than 1 and where STAs are located closer from their serving APs (good SNR conditions) than from neighboring APs on the same channel.

It is regular

Reuse 1 should however also be considered, to capture the fact that some regions have very low available bandwidth and are forced to apply frequency reuse 1 deployments. (But this reuse 1 case is very difficult seeing the huge overlap between neighboring APs due to high density of APs).

Note that frequency reuse 1 is more suited to scenario 4 either to represent:

A single operator deployment in a region where available bandwidth is low (the lower density of APs in large outdoor makes it more realistic)

An overlap between 3 operators, each applying a frequency reuse 3: this is equivalent to a single deployment with reuse 1.

In order to focus this scenario on the issues related to high density, the channel model is considered as a large indoor model (TGn F). *Note that robustness to outdoor channel models, which is also a requirement for some usage models in category 1 (like outdoor stadiums), is captured in the outdoor large BSS scenario.*

It is important to define a proportion (TBD %) of legacy devices in the scenario that won’t implement the proposed solution under evaluationto ensure that the solution will keep its efficiency in real deployments (some solutions may be sensitive to the presence of legacy devices while other won’t).

These legacy devices shall simply keep the baseline default parameters and shall not implement the proposed solution under evaluation. Those devices can be:

* STAs connected to the planned network
* APs and STAs part of the interfering network

|  |  |
| --- | --- |
| **Parameter** | **Value** |
|  | |
| **Topology (A)** | |
| Figure 6 - BSSs layout (partial)  BSS  BSS  BSS  BSS  BSS  BSS  BSS  BSS  BSS  BSS  BSS  BS  BSS  BSS  BSS  BSS  BSS  BSS  BSS  Figure 7 - Layout of BSSs using the same channel in case frequency reuse 3 is used | |
| Environment description | BSSs are placed in a regular and symmetric grid as in Figure 6 for frequency reuse 1 and Figure 7 for frequency reuse 3.  Each BSS in Figure 6 has the following configuration:  BSS radius: R meters (7m [#1248] / 12m [Stadium, #722,#1079] TBD)  Inter BSS distance (ICD): 2\*h meters  h=sqrt(R2-R2/4) |
| APs location | AP is placed at the center of the BSS, with antenna height TBD |
| AP Type | {HEW} |
| STAs location | STAs are placed randomly in a BSS |
| Number of STA and STAs type | N STAs in each BSS. STA\_1 to STA\_{N1}: HEW STA\_{N1+1} to STA\_{N} : non-HEW (N = 30 [#1248] -72 [Stadium, #722,#1079] (TBD), N1 = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz |
| Channel Model | AP-AP: TBD  STA-STA: TGac channel model B  Option 1.  AP-STA: TGac channel model D  Option2.  AP-STA: ITU InH model w/3D |
| Penetration Losses | None |
|  | |
| **PHY parameters** | |
| Center frequency and BW | All BSSs either all at 2.4GHz, or all at 5GHz  {20MHz BSS at 2.4GHz, 80 MHz BSS at 5GHz} |
| MCS | {Up to MCS 9, BCC} |
| GI | [Long] |
| Data Preamble | [2.4GHz, 11n; 5GHz, 11ac] |
| STA TX power | [max 15dBm] (#1248) [max 19dBm] (#1079) |
| AP TX Power | [max 17dBm] |
| AP #of TX antennas | {2, 4} |
| AP #of RX antennas | {2, 4} |
| STA #of TX antennas | {1, 2} |
| STA #of RX antennas | {1, 2} |
|  | |
| **MAC parameters** | |
| Access protocol parameters | [EDCA with default EDCA Parameters set] |
| Primary channels | [] |
| Aggregation | [A-MPDU / max aggregation size / BA window size, No A-MSDU, with immediate BA] |
| Max # of retries | [10] |
| RTS/CTS Threshold | [TBD] |
| Association | [X% of STAs are associated with the strongest AP, Y% of STAs are associated with the second-strongest AP, and Z% of STAs associate with the third-strongest AP. Z% of STAs are not associated. Detailed distribution to be decided.] |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (per each BSS) - TBD** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| D1 | AP/STA1 to AP/STA10 | Highly compressed video (streaming) | T2 |  |  |
| D2 | AP/STA11 to AP/STA20 | Web browsing | T4 |  |  |
| D3 | AP/STA21 to AP/STA30 | Local file transfer | T3 |  |  |
| **Uplink** | | | | | |
| U1 | STA1/AP to STA10/AP | Highly compressed video (streaming) – UL TCP ACKs… |  |  |  |
| U2 | STA11/AP to STA20/AP | Web browsing: – UL TCP ACKs… |  |  |  |
| U3 | STA21/AP to STA30/AP | Local file transfer | T3 |  |  |
| **P2P** | | | | | |
| P1 | NONE (see interfering scenarios) |  |  |  |  |
| **Idle / Management** | | | | | |
| M1 | AP | Beacon | TX |  |  |
| M2 | STA36 to STA TBD | Probe Req. | TY |  |  |

## Interfering Scenario for Scenario 3

This scenario introduces and overlay of unmanaged P2P networks on top of Scenario 3.

|  |  |  |
| --- | --- | --- |
| **Parameter** | | **Value** |
|  | | |
| **Topology** | | |
| BSS  BSS  BSS  BSS  BSS  BSS  BSS  Figure 8 - BSSs layout, with interfering P2P links | | |
| Topology Description | K P2P pairs of STAs | |
| APs location | Pairs randomly placed in simulation area | |
| AP Type |  | |
| STAs location | STAs pairs randomly placed in the simulation area  Per each pair, STAs are placed 0.5m apart | |
| Number of STA and STAs type | STA\_1 to STA\_{K1}: HEW STA\_{K1+1} to STA\_{K} : non-HEW (K = TBD, K1 = TBD) | |
| Channel Model | TBD | |
| Penetration Losses | None | |
|  | | |
| **PHY parameters: Same as main scenario**  **Except for the following ones** | | |
| STA TX Power | TBD | |
|  | | |
| **MAC parameters: same as main scenario**  **Except for the following ones** | | |
| Primary channels | **TBD** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model for interfering scenario** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| 1 | STA\_1 to STA\_2 | Highly compressed video (streaming) | T2 |  |  |
| 2 |  |  |  |  |  |
| 3 | STA\_n to STA\_{n+1} | Local file transfer | T3 |  |  |
| **Idle / Management** | | | | | |
| M1 | STA\_{2n} | Beacon | TX |  |  |

# 4 - Outdoor Large BSS Scenario

This scenario has the objective to capture the issues (and be representative of) real-world outdoor deployments with a high separation between APs (BSS edge with low SNR) with high density of STAs that are highlighted by the forth category of usage models described in []:

* In such environments, the infrastructure network (ESS) is planned. For simulation complexity simplifications, a hexagonal BSS layout is considered with a frequency reuse pattern. This frequency reuse pattern is defined and fixed, as part of the parameters that can’t be modified in this scenario. *(Note that BSS channel allocation can be evaluated in simulation scenarios where there are not planned networks (ESS), as in the residential one.)*
* In such environments, the “traffic condition” described in the usage model document mentions:
  + interference between APs belonging to the same managed ESS due to high density deployment: *this OBSS interference is captured in this scenario even if it is low as the distance between APs is high*
  + Interference with unmanaged networks (P2P links): *this OBSS interference is currently not captured in this scenario, but in the scenario 3.*
  + Interference with unmanaged stand-alone APs: *this OBSS interference is currently not captured in this scenario, but in the hierarchical indoor/outdoor scenario 4a*
  + Interference between APs belonging to different managed ESS due to the presence of multiple operators: *this OBSS interference is captured in this scenario, by an overlap of 3 operators, using relatively similar grid but channel selection offset*

Reuse factor, TBD

We should consider a hexagonal deployment using frequency reuse 1.

Such a frequency reuse 1 scenario is representative of:

A single operator deployment in a region where available bandwidth is low and forces frequency reuse 1 deployments (the lower density of APs in large outdoor makes it more realistic)

An overlap between 3 operators, each applying a frequency reuse 3: in case of close location of this is equivalent to a single operator deployment with reuse 1.

As the inter-site distance is high, the overlap between neighboring cells is close to minimum sensitivity (low SNR)

* *this enables to capture the issue of outdoor performance in low SNR conditions*
* *this enables to capture the issue of fairness between users spread on the full coverage of each AP*
* *this enables to capture OBSS interference touching STAs in low SNR conditions (far from their serving APs), while in dense hotspot scenario, the OBSS interference is touching STAs in high SNR conditions (close to their serving APs)*

It is important to define a proportion (TBD %) of legacy devices in the scenario that won’t implement the proposed solution under evaluationto ensure that the solution will keep its efficiency in real deployments (some solutions may be sensitive to the presence of legacy devices while other won’t).

These legacy devices shall simply keep the baseline default parameters and shall not implement the proposed solution under evaluation. Those devices can be:

* STAs connected to the planned network
* APs and STAs part of the interfering network

|  |  |
| --- | --- |
| **Parameter** | **Value** |
|  | |
| **Topology (A)** | |
| Figure 9 – BSSs layout | |
| Environment description | Outdoor street deployment  Overlap of 3 operators  BSS layout configuration  Define a 19 hexagonal grid as in Figure 9  With ICD = 2\*h meters (130m, TBD)  h=sqrt(R2-R2/4) |
| APs location | Place APs on the center of each BSS, +/- an offset with TBD standard deviation, with antenna height TBD m. |
| AP Type | {HEW} |
| STAs location | STAs are placed randomly in a BSS. |
| Number of STA and STAs type | N STAs in each BSS.  STA\_1 to STA\_{N1}: HEW STA\_{N1+1} to STA\_{N} : non-HEW (N= 50 - 100 TBD, N1 = TBD)  Non-HEW = 11b/g (TBD) in 2.4GHz  Non-HEW = 11ac (TBD) in 5GHz |
| Channel Model | {UMi} [UMa]  TBD Note: In case of UMi channel model, M.2135-1 defines that 50% of user are indoor users, but since indoor users can be served by indoor AP, we can change the percentage of users are indoor; need to decide which percentage |
| Penetration Losses | None |
|  | |
| **PHY parameters** | |
| Center frequency and BW | All BSSs either all at 2.4GHz, or all at 5GHz  {20MHz BSS at 2.4GHz, 80 MHz BSS at 5GHz} |
| MCS | {Up to MCS 9, BCC} |
| GI | [long] |
| Data Preamble | [2.4GHz, 11n; 5GHz, 11ac] |
| STA TX power | [15dBm] |
| AP TX Power | [30dBm] |
| AP #of TX antennas | {2, 4} |
| AP #of RX antennas | {2, 4} |
| STA #of TX antennas | {1, 2} |
| STA #of RX antennas | {1, 2} |
|  | |
| **MAC parameters** | |
| Access protocol parameters | [EDCA with default EDCA Parameters set] |
| Primary channels | {Frequency reuse 1 is considered: all BSSs are using the same 80MHz channel}  [Primary channel position TBD] |
| Aggregation | [A-MPDU / max aggregation size / BA window size, No A-MSDU, with immediate BA] |
| Max # of retries | [10] |
| RTS/CTS Threshold | [TBD] |
| Association | [X% of STAs are associated with the strongest AP, Y% of STAs are associated with the second-strongest AP, and Z% of STAs are associated with the third-strongest AP. Z% of STAs are not associated. Detailed distribution to be decided.] |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (Per each BSS) - TBD** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| D1 | AP/STA1 to AP/STA10 | Highly compressed video (streaming) | T2 |  |  |
| D2 | AP/STA11 to AP/STA20 | Web browsing | T4 |  |  |
| D3 | AP/STA21 to AP/STA25 | Local file transfer | T3 |  |  |
| … | … |  |  |  |  |
| DN | AP/STAN |  |  |  |  |
| **Uplink** | | | | | |
| U1 | AP/STA1 to AP/STA10 | Highly compressed video (streaming) – UL TCP ACKs… |  |  |  |
| U2 | AP/STA11 to AP/STA20 | Web browsing: – UL TCP ACKs… |  |  |  |
| U3 | STA26/AP to STA30/AP | Local file transfer | T3 |  |  |
| … | … |  |  |  |  |
| UN | STAN/AP |  |  |  |  |
| **P2P** | | | | | |
| P1 | STA1/AP |  |  |  |  |
| P2 | STA2/AP |  |  |  |  |
| P3 | STA3/AP |  |  |  |  |
| … | … |  |  |  |  |
| PN | STAN/AP |  |  |  |  |
| **Idle Management** | | | | | |
| M1 | AP1 | Beacon | TX |  |  |
| M2 | STA2 | Probe Req. | TY |  |  |
| M3 | STA3 |  |  |  |  |
| … | … |  |  |  |  |
| MN | STAN |  |  |  |  |

# 4a- Outdoor Large BSS + Residential Scenario

|  |  |  |
| --- | --- | --- |
| **Parameter** | | **Value** |
|  | | |
| **Topology (A)** | | |
| Figure 10 –Layout of large BSSs with residential buildings | | |
| Environment description | This scenario consists of an overlay of the following   * Scenario 4, with the exception that only 7 cells are included out of the 19 * A Residential building per each BSS, which center is placed in a random uniform position within a radius of ICD/2 around the AP; the Residential building topology is as defined in Scenario 1, with the exception that the number of floors is set to 1. | |
| APs location | See Scenario 1 and 4. | |
| AP Type | See Scenario 1 and 4. | |
| STAs location | See Scenario 1 and 4. | |
| Number of STA and STAs type | See Scenario 1 and 4. | |
| Channel Model | See Scenario 1 and 4  {indoor/outdoor??} | |
| Penetration Losses | See Scenario 1 and 4. | |
|  | | |
| **PHY parameters** | | |
| Same parameters as defined for the STAs in Scenario 1 and Scenario 4. | | |
|  | | |
| **MAC parameters** | | |
| All parameters except the ones listed in this table are same as in Scenario 1 and Scenario 4 | | |
| Association | STAs defined by Scenario 1, associate as defined by Scenario 1  STAs defined by Scenario 4:  80% associate as defined by Scenario 4  20% associate with strongest AP from a Residential building | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (Per each BSS) - TBD** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| Traffic model for STAs defined by Scenario 1, is defined by Scenario 1 | | | | | |
| Traffic model for STAs defined by Scenario 2, is defined by Scenario 2 | | | | | |

# Annex 1 - Reference traffic profiles per scenario

**Reference traffic profile for Scenario 1**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic Model #** | **Traffic model name** | **Description** | **Application traffic**  **(Forward / Backward)** | **Application Load (Mbps)**  **(Forward / Backward)** | **A-MPDU Size (B)**  **(Forward / Backward)** |
| T1 | Local file transfer | FTP/TCP transfer of large file within local network | FTP file transfer  / FTP TCP ACK | Full buffer /  0.1 | Max A-MPDU / 64 |
| T2 | Lightly compressed video |  |  |  |  |
| T3 | Internet streaming video/audio |  |  |  |  |
| T4 | 4k video streaming |  |  |  |  |
| T5 | Online game server |  |  |  |  |
| T6 | Management: Beacon |  |  |  |  |
| T7 | Management: Probe requests |  |  |  |  |

**Reference traffic profile for Scenario 2**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic Model #** | **Traffic model name** | **Description** | **Application traffic**  **(Forward / Backward)** | **Application Load (Mbps)**  **(Forward / Backward)** | **A-MPDU Size (B)**  **(Forward / Backward)** |
| T1 | Local file transfer | FTP/TCP transfer of large file within local network | FTP file transfer  / FTP TCP ACK | Full buffer /  0.1 | Max A-MPDU / 64 |
| T2 | Lightly compressed video |  |  |  |  |
| T3 | Internet streaming video/audio |  |  |  |  |
| T4 | 4k video streaming |  |  |  |  |
| T5 | Online game server |  |  |  |  |
| T6 | Management: Beacon |  |  |  |  |
| T7 | Management: Probe requests |  |  |  |  |

**Reference traffic profile for Scenario 3**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic Model #** | **Traffic model name** | **Description** | **Application traffic**  **(Forward / Backward)** | **Application Load (Mbps)**  **(Forward / Backward)** | **A-MPDU Size (B)**  **(Forward / Backward)** |
| T1 | Local file transfer | FTP/TCP transfer of large file within local network | FTP file transfer  / FTP TCP ACK | Full buffer /  0.1 | Max A-MPDU / 64 |
| T2 | Lightly compressed video |  |  |  |  |
| T3 | Internet streaming video/audio |  |  |  |  |
| T4 | 4k video streaming |  |  |  |  |
| T5 | Online game server |  |  |  |  |
| T6 | Management: Beacon |  |  |  |  |
| T7 | Management: Probe requests |  |  |  |  |

**Reference traffic profile for Scenario 4**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic Model #** | **Traffic model name** | **Description** | **Application traffic**  **(Forward / Backward)** | **Application Load (Mbps)**  **(Forward / Backward)** | **A-MPDU Size (B)**  **(Forward / Backward)** |
| T1 | Local file transfer | FTP/TCP transfer of large file within local network | FTP file transfer  / FTP TCP ACK | Full buffer /  0.1 | Max A-MPDU / 64 |
| T2 | Lightly compressed video |  |  |  |  |
| T3 | Internet streaming video/audio |  |  |  |  |
| T4 | 4k video streaming |  |  |  |  |
| T5 | Online game server |  |  |  |  |
| T6 | Management: Beacon |  |  |  |  |
| T7 | Management: Probe requests |  |  |  |  |

# Annex 2 – Traffic model descriptions

**Wireless Display (lightly compressed video) Traffic Model**

Wireless display is a single-hop unidirectional (e.g., laptop to monitor) video application. The video slices (assuming a slice is a row of macro blocks) are generated at fixed slice interval. For example, for 1080p, the slice interval is 1/4080 seconds.

The video slices are typically packetized into MPEG-TS packets in wireless display application. But for HEW simulation, we will ignore the MPEG-TS packetization process and assume video slices are delivered to MAC layer for transmission directly.

The traffic model for wireless display is modified from [TGad] with modifications below due to the fact that some parameters have dependency on video formats.

1. Parameters
   1. Set **IAT**, **MaxSliceSize** according to video format as Table xx.
   2. Normal distribution parameters
      1. µ = 15.798 Kbytes
      2. σ = 1.350 Kbytes
      3. b = 300 Mbps
2. Algorithm for generating each video slice/packet

* Input: target bit rate in Mbps (**p**)
* Output: slice size in Kbytes (L): At each IAT, generate a slice size L with the following distribution: Normal(µ\*(p/b), σ\*(p/b))
  + - If L > MaxSliceSize, set L= MaxSliceSize

|  |  |  |  |
| --- | --- | --- | --- |
| **Video format** | **Inter-arrival time (IAT)** | **MaxSliceSize** | **p** |
| 1080p60 | 1/4080 seconds | 92.160 Kbytes | 300 |
| 4K UHD (3840x2160) 60fps | 1/8100 seconds | 184.320 Kbytes | 600 |
| 8K UHD (7680x4320) 60fps | 1/16200 seconds | 368.640 Kbytes | 1200 |
| 1080p60 3D | 1/4080 seconds | 92.160 Kbytes | 450 |

Note: the data rate increase from 1080p to higher resolution is not linearly scaling as the uncompressed data rate due to higher redundancy in the images at higher resolution. Similar argument applies to 3D video. A 100% increase is assumed for 4K video as compared to 1080p, and 50% bit rate increase for 3D from 2D video.

**Evaluation metric**

* MAC throughput, latency

**Buffered Video Steaming (e.g., YouTube, Netflix) Traffic Model**

Unlike wireless display, video streaming is generated from a video server, and traverses multiple hops in the internet before arriving at AP for transmission to STA. It is a unidirectional traffic from the video server to the station.

Typically, Video streaming application runs over TCP/IP protocol, and video frames will be fragmented at TCP layer before leaving the video server. Since these TCP/IP packets experiences different processing and queuing delay at routers, the inter-arrival time between these TCP/IP packets are not a constant despite the fact that video frames are generated at constant interval at the video application layer.

**STA Layering Model**

STA layering model is shown in Figure xx. Both AP and STA generate video frames at application layer. The video traffic goes through TCP/IP layer and then to MAC layer. The TCP protocol used for video streaming simulation is the same as other traffic model described in section x.x. of this document.



Figure xx Traffic layering model

**Video traffic generation**

The video traffic from AP to STA is generated as follows.

**Step 1**: At application layer, generate video frame size (bytes) according to Weibull distribution with the following PDF.


f(x;\lambda,k) =
\begin{cases}
\frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1}e^{-(x/\lambda)^{k}} & x\geq0 ,\\
0 & x<0,
\end{cases}

Depending on the video bit rate, the parameters to use are specified in Table 1.

|  |  |  |
| --- | --- | --- |
| **Video bit rate** | **lambda** | **k** |
| 10Mbps | 34750 | 0.8099 |
| 8Mbps | 27800 | 0.8099 |
| 6Mbps | 20850 | 0.8099 |
| 4Mbps | 13900 | 0.8099 |
| 2Mbps | 695 | 368.640 Kbytes |

Table 1 lambda and k parameter for video bit rate

**Step 2**: AT TCP layer, set TCP segment as 1500 bytes and fragment video packet into TCP segments.

**Step 3**: Add network latency to TCP/IP packets when these segments arrive at AP for transmission. The network latency is generated according to Gamma distribution whose PDF is shown below

f(x;k,\theta) =  \frac{x^{k-1}e^{-\frac{x}{\theta}}}{\theta^k\Gamma(k)} \quad \text{ for } x > 0 \text{ and } k, \theta > 0.

Where

* + k=0.2463
  + theta=55.928

The mean of the latency with the above parameters is 14.834ms. To simulate longer or shorter network latency, scale theta linearly since mean of Gamma distribution is K\*theta

If network latency value is such that the packet arrives at MAC layer after the end of the simulation time, then re-generate another network latency value until the packet arrives at MAC within the simulation window.

**Evaluation metrics**

* MAC throughput, latency
* TCP throughput, latency

**Video Conferencing (e.g., Lync) Traffic Model**

Unlike video conferencing where video traffic is unidirectional, video conferencing is two-way video traffic. The video traffic is generated at each station, send to AP, transverse the internet and reach another AP and then send to the destination.

**Station layer model**



Because the traffic from AP to station has experienced network jitter, it can be modelled the same way as the traffic model of video streaming.

For the traffic sent from Station to AP, since the traffic has not experienced network jitter, it is a periodic traffic generation as the first two steps described in video streaming.

**Video traffic generation**

Traffic model from AP to station: use the same model as video streaming.

Traffic model from station to AP: use the first two steps in video streaming traffic model

**Evaluation metrics**

* MAC throughput, latency

**Management traffic profiles**

Unassociated clients probe all possible channels periodically until they associate to an AP. Even after association, while they are in sleep mode (e.g. the smartphone screen is off) they would wake up for a short time and probe the AP they are associated to (e.g. to check whether there are updates in the status of some applications, like whether an instant messaging server has a new message for the instant messaging client on the smartphone).

While probing may not generate significant management traffic per client, in high-density environments the probing traffic adds up and can consume a considerable percentage of the wireless medium. This becomes significant in use cases like stadiums, airports etc. This annex proposes management traffic models for associated and unassociated clients.

**Management traffic model for unassociated clients:**

* Probing period:
  + For {50%} of the clients: [12 seconds]
  + For {50%} of the clients:
    - [12 seconds]
    - If still unassociated after [5] times probing all the channels, then probe all the channels every [25 seconds].
    - If still unassociated after [5] times probing all the channels, then probe all the channels every [50 seconds].
    - If still unassociated after [5] times probing all the channels, then probe all the channels every [100 seconds].
    - If still unassociated after [5] times probing all the channels, then probe all the channels every [200 seconds].
    - If still unassociated after [5] times probing all the channels, then probe all the channels every [400 seconds].
* Probing channels: Every supported channel [1,2,3,4..,36,40,..]
* Probe request SSID: Broadcast probe requests to wildcard SSID, plus [0-3] specified SSIDs

**Management traffic model for associated clients:**

* Probing period: [60 seconds]
* Probing channels: Same channel that the client is associated, unless the associated AP Beacon’s RSSI is below [TBD dBm] in which case probe every supported channel [1,2,3,4..,36,40,..]

Probe request SSID: Probe the associated AP/SSID if RSSI is not below [TBD dBm], otherwise broadcast probe requests to wildcard SSID

**Annex 1.2 Application event models**

Application event model is used to specify the patterns of the application events, i.e., when to start the applications and how long for each application in the simulation. Different use scenarios may choose different application event models in the simulation.

* Poisson model

Poisson model can be used for random application event pattern where there are many users, each generating a little bit of traffic and requesting network access randomly.

Parameters: TBD

* Hyper-exponential model

Hyper-exponential model can be used for peak event pattern where users requesting network access in big spikes from the mean.

Parameters: TBD

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# Annex 3 - Templates

|  |  |  |
| --- | --- | --- |
| **Parameter** | | **Value** |
|  | | |
| **Topology** | | |
| Figures | | |
| Environment description |  | |
| APs location |  | |
| AP Type |  | |
| STAs location |  | |
| Number of STA and STAs type |  | |
| Channel Model |  | |
| Penetration Losses |  | |
|  | | |
| **PHY parameters** | | |
| Center frequency and BW |  | |
| MCS |  | |
| GI |  | |
| Data Preamble: |  | |
| STA TX power |  | |
| AP TX Power |  | |
| AP #of TX antennas |  | |
| AP #of RX antennas |  | |
| STA #of TX antennas |  | |
| STA #of RX antennas |  | |
|  | | |
| **MAC parameters** | | |
| Access protocol parameters |  | |
| Primary channels |  | |
| Aggregation |  | |
| Max # of retries |  | |
| RTS/CTS Threshold |  | |
| Association |  | |

**Traffic model**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Traffic model (Per each apartment) - TBD** | | | | | |
| **#** | **Source/Sink** | **Name** | **Traffic definition** | **Flow specific parameters** | **AC** |
| **Downlink** | | | | | |
| D1 | AP/STA1 | 4k Video | T1 |  | VI |
| D2 | AP/STA2 | Local file transfer | T3 |  | BE |
| D3 | AP/STA3 | … |  |  |  |
| … | … |  |  |  |  |
| DN | AP/STAN |  |  |  |  |
| **Uplink** | | | | | |
| U1 | STA1/AP |  |  |  |  |
| U2 | STA2/AP |  |  |  |  |
| U3 | STA3/AP |  |  |  |  |
| … | … |  |  |  |  |
| UN | STAN/AP |  |  |  |  |
| **P2P** | | | | | |
| P1 | STA1/AP |  |  |  |  |
| P2 | STA2/AP |  |  |  |  |
| P3 | STA3/AP |  |  |  |  |
| … | … |  |  |  |  |
| PN | STAN/AP |  |  |  |  |
| **Idle Management** | | | | | |
| M1 | AP1 | Beacon | TX |  |  |
| M2 | STA2 | Probe Req. | TY |  |  |
| M3 | STA3 |  |  |  |  |
| … | … |  |  |  |  |
| MN | STAN |  |  |  |  |

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2. **11-13/0722r1, “HEW Evaluation Methodology”, Minyoung Park (Intel)**
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6. **11-13/0795, “Usage scenarios categorization”, Eldad Perahia (Intel)**
7. **11-13/0800, “HEW Study Group Documentation”, Hemanth Sampath  (Qualcomm)**
8. **11-13/0802, “Proposed re-categorization of HEW usage Models”, Yasuhiko Inoue (NTT)**
9. **11-13/0847, “Evaluation Criteria and Simulation Scenarios”, Klaus Doppler (Nokia)**
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1. **11-13/1000r2 Simulation Scenarios, Simone Merlin (Qualcomm)**
2. **11-13/1083r0 HEW SG Unified Simulation Scenarios, David Xun Yang (Huawei)**
3. **11-13/1079r0 Outdoor Stadium Simulation Details Discussion, Joseph Levy (InterDigital)**
4. **11-13/1081 HEW Simulation Methodology, Sayantan Choudhury (Nokia)**
5. **11-13/1114 Simulation scenario for unplanned Wi-Fi network, Minho Cheong (ETRI)**
6. **11-13/1153 Simulation scenario proposal, Laurent Cariou (Orange)**
7. **11-13/1176r0 Some Simulation Scenarios for HEW, Reza Hedayat (Cisco Systems)**
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* **11-13/1305, Traffic Simulation Simplifications, William Carney (SONY)**
* **11-13/1334/5, Video Traffic Modeling--word with details, Guoqing Li (Intel)**
* **11-13/1383 System Level Simulation Parameters, Wookbong Lee (LGE)**
* **11-13/1392 Methodology of calibrating system simulation results Yan Zhang (Marvell)**

**JanuARY 2014**

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