IEEE802.11ax - High Efficiency WLAN (HEW) Standardization and Potential Technologies

June 3rd, 2014
Veli-Pekka Ketonen
CTO, 7signal Solutions
Content

1. Why is a new Wi-Fi standard needed?
   - We are just getting -ac…
   - What are the next main bottlenecks?

2. 802.11ax overview
   - Adopted directly from IEEE High Efficiency WLAN Overview

3. Selected technology contributions
   - Adopted from IEEE 802.11HEW/ax SG/TG contributions

4. The latest schedule contributions
   - Based on recent IEEE802.11ax contribution

5. Could 802.11ax Wi-Fi 2020 look like this?
Why is new Wi-Fi standard needed?

What are the bottlenecks in current and near term Wi-Fi?

Veli-Pekka Ketonen
Main Wi-Fi bottlenecks, 1/2

- **Current CCA protocol is over-protective in dense areas**
  - Wi-Fi radios hold back and do not transmit

- **Retransmissions are inefficient and use a lot airtime**
  - Wi-Fi network have a lot of retransmissions consuming airtime
  - Need a perfect packet delivery, information is not combined between successive retries

- **RF spreads evenly everywhere**
  - RF is sent to all directions and receiver tries to receive it from all directions
  - Benefits of antenna directivity and beam steering are not yet in use

- **No dynamic transmit power control**
  - Near by devices transmit static high power levels

- **Control and management traffic takes a lot of airtime from user data**
  - In dense areas, majority of packets are control and management frames

- **Legacy device protection reduces network capacity significantly**
  - Legacy devices are over protected, benefits of new technologies are reduced

- **Mobile/cellular networks interfere Wi-Fi**
  - Co-existence has not been considered, lacking especially RF filtering at Wi-Fi
Main Wi-Fi bottlenecks, 2/2

- **Channel access** gets congested with large amount of devices
  - Channel access is contention based and efficiency could be better
- **Wi-Fi signal processing** does not work well with large delay spread
  - Large delay spread causes receivers problems decoding the data
- **One size fits all** -- Home Wi-Fi = Stadium Wi-Fi = Medical Wi-Fi
  - No differentiation in operation or capability to optimize towards needs
- **Radio traffic flows** not properly prioritized for system level capacity
  - Protocols are inefficient with high load, clients and APs are equal
- **Wi-Fi lacks performance management capability**
  - No visibility to user experience and capability optimize network
- **Wi-Fi is half duplex technology** -- cannot receive when transmits
  - This cuts efficiency by 50%
- **New use cases** have not been considered with the 802.11 standard
  - Wi-Fi is used in ways which were not considered during standardization
- **Use of spectrum, time and spatial dimensions** could be enhanced
  - Current technologies allow more efficient operation
High Efficiency WLAN Overview (802.11ax)

MODIFIED FROM ORIGINAL PRESENTATION AT:
IEEE 802.11-14/0214r2
https://mentor.ieee.org/802.11/dcn/14/11-14-0214-02-0hew-overview.pptx

Date: 2014-02-18

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Adopted and abbreviated by Veli-Pekka Ketonen
Introduction and problem statement (1/2)

- The vast majority of deployments will evolve towards high density scenarios in the near future
  - Usage models in such scenarios are likely to suffer bottlenecks in the coming years, with inefficiencies in transforming the multi-Gbps peak capacity into real throughput experienced by users

- HEW aims to achieve a very substantial increase in the real-world throughput achieved by users in such scenarios, with improved power efficiency for battery powered devices
  - Creating an instantly recognizable improvement in User Experience of the major use cases
IEEE 802.11 HEW SG* is proposing a PAR** for a TG*** to create an amendment to 802.11 for operations in frequency bands between 1 GHz and 6 GHz
- Focused primarily on 2.4 GHz and the 5 GHz frequency bands

Expected MAC and PHY modifications in focused directions:
- (1) To improve efficiency in the use of spectrum resources in dense networks with large no. of STAs and large no. of APs
- (2) To improve efficiency and robustness in outdoor deployments
- (3) To improve power efficiency

*Study group ** Project authorization request *** Task Group
Market Drivers

Various market segments require enhancement of average throughput and user experience in dense deployment scenarios

- Operators desire **cellular offload** to lighten traffic explosion
- PC/Mobile/CE vendors desire **higher user experience**
- **Automotive** is increasingly using Wi-Fi for in-car entertainment
- Chip/AP vendors desire **successive Wi-Fi market evolution** after 11ac

Need a standard to enhance average throughput and user experience in real world
Need for the Project

- Very dense deployments
- Growing use of WLAN outdoors
- Better support of real-time applications with improved power efficiency
- Focusing on improving metrics that reflect user experience in typical conditions
Environments discussed in the study group include:

- Airport/Train Station
- Hospitals
- Public Transportation
- Dense Apartment Buildings
- Enterprise
- Hotspot in Public Places
- Small Office
- Pico-cell Street Deployments
- e-Education
- Outdoor Hotspots
New and Enhanced Applications

- Cellular Offloading
- Cloud Computing - including VDI
- Display Sharing - 1-to-1, 1-to-many, Many-to-1
- Interactive Multimedia & Gaming
- Progressive Streaming
- Real-time Video Analytics & Augmented Reality
- Support of wearable devices
- Unified Communications - Including Video conf.
- User Generated Content (UGC) Upload & Sharing
- Video conferencing/tele-presence
- Video distribution at home – (VHD, UHD)
- Wireless docking
## HEW Differentiating Features

<table>
<thead>
<tr>
<th></th>
<th>Previous 802.11 Amendments</th>
<th>HEW Amendments being considered</th>
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<tr>
<td><strong>Objectives</strong></td>
<td>Increase the per-link peak throughput</td>
<td>Increase the average per STA throughput in dense environments</td>
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<tr>
<td><strong>Scenarios</strong></td>
<td>Single application for a single client in indoor situations</td>
<td>Dense deployment environments with a mix of clients/APs and traffic types including outdoor situations</td>
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<tr>
<td><strong>KPIs/Metrics</strong></td>
<td>Peak rate driven - Link throughput, - Aggregate throughput</td>
<td><strong>User Experience Driven</strong></td>
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<tr>
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<td></td>
<td>- Average per station throughput,</td>
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<td>- 5&lt;sup&gt;th&lt;/sup&gt; %ile per station throughput,</td>
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<tr>
<td></td>
<td></td>
<td>- Area throughput</td>
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<tr>
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<td>- Power efficiency</td>
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Technologies (1 of 2)

- HEW will consider **MAC and PHY technologies** that significantly improve WLAN efficiency and robustness:
  - Make more **efficient use of spectrum resources** in scenarios with a high density of STAs per BSS.
  - Significantly **increase spectral frequency reuse** and manage interference between neighboring overlapping BSS (OBSS) in scenarios with a high density of both STAs and BSSs.
  - **Increase robustness** in outdoor propagation environments and uplink transmissions.
  - Maintain or **improve the power efficiency** per station

- The next slides lists technology discussions
  - The list does not represent technologies agreed for inclusion in the standard
  - Technologies, not listed on the next slide, could also be considered for inclusion in the standard.
Technologies discussed in the study group include:

<table>
<thead>
<tr>
<th>Edge Throughput Enhancement</th>
<th>Multiplexing Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ HARQ (Hybrid Automatic Repeat Req.)</td>
<td>➢ OFDMA, SDMA, OFDM-IDMA, FFR</td>
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<tr>
<td>➢ Larger CP (Contention Period)</td>
<td>➢ TD-uCSMA</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>MAC Enhancements</th>
<th>Overlapping BSS Handling</th>
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<tbody>
<tr>
<td>➢ Basic Access Mechanism enhancements</td>
<td>➢ Interference management, Antenna pattern nulling</td>
</tr>
<tr>
<td>➢ Dynamic Sensitivity Control</td>
<td>➢ Efficient resource utilization</td>
</tr>
<tr>
<td>➢ Traffic Prioritization, QoE</td>
<td>➢ Control frame transmission reduction</td>
</tr>
<tr>
<td>➢ Multicast transmissions</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>MIMO/Beamforming</th>
<th>Simultaneous Transmit and Receive</th>
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<tbody>
<tr>
<td>➢ Massive MIMO, MIMO Precoding</td>
<td>➢ MAC/PHY mechanisms for enabling In-Band STR</td>
</tr>
<tr>
<td>➢ DL/UL MU-MIMO</td>
<td>➢ Enhancements for enabling out-Band STR</td>
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<tr>
<td>➢ Beamforming for OBSS</td>
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<tr>
<td>➢ Beamforming for Interference Handling</td>
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HEW PAR* Scope

- **Four times improvement** in the average throughput per station in a dense deployment scenario
  - Throughput is measured at the MAC data service access point
  - Expected to provide improvements of 5 – 10x

- Maintaining or improving the power efficiency per station

- Indoor and outdoor operations in frequency bands **between 1 GHz and 6 GHz**

- Enabling backward compatibility and coexistence with legacy IEEE 802.11 devices operating in the same band

*Project authorization request*
2. Excerpts from selected IEEE802.11ax/HEW contributions

Adjusted for better presentation visibility

IEEE Mentor server:
https://mentor.ieee.org/802.11/documents?is_dcn=DCN%2CTitle%2CAuthor%20or%20Affiliation&is_group=0hew
DSC – Dynamic Sensitivity Control

Dynamic Sensitivity Control for HEW SG

Date: 2013-11

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**Background**

- 802.11 uses CSMA/CA carrier sense multiple access with collision avoidance.
- STA listens before transmitting
- Two methods of sensing the medium
  - Physical Carrier Sense
    Is there RF energy present?
  - Virtual Carrier Sense
    Is there an 802.11 signal present?
- Clear Channel Assessment (CCA)
  - OFDM transmission => minimum modulation and coding rate sensitivity (6Mbps)
    (-82dBm for 20MHz channel, -79dBm for 40MHz channel)
  - If no detected header, 20 dB higher, i.e. -62dBm
Example – background to idea

- AP1 to STA A -50dBm, (also AP2 to STA B)
- STA B is 4x as far from AP 1 as STA A.
  - Therefore AP1 receives STA B at -80dBm (50 + 20* +10 wall) *10dB per octave
  - STA A receives TX from STA B at -70dBm (50 +10* +10wall)

Note: AP1 receives AP2 <-82dBm so CCA is not exerted

STA A and STA B could both transmit successfully to their APs at the same time BUT each is prevented by CCA.
Dynamic Sensitivity Control - DSC

- Imagine a scheme where STA measures the RSSI of the AP Beacon (R dBm)
- Then sets its RX Sensitivity Threshold at (R – M) dBm, where M is the “Margin”
- Hence, for example:
  - STA receives Beacon at -50dBm, with Margin = 20dB
    STA sets RX Sensitivity Threshold to -70dBm.
- Also set an Upper Limit, L, to Beacon RSSI at, say, -30 or -40dBm to cater for case when STA is very close to AP.
  - Need to ensure that all the STAs in the wanted area do see each other. Hence if one STA very close to AP, then it could set RX Sensitivity too high.
DSC – Dynamic Sensitivity Control

MAC simulation results for Dynamic sensitivity control (DSC - CCA adaptation) and transmit power control (TPC)

Authors: Date: 2014-04-17

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</table>
How to enable reuse?

1: Transmit power control

2: CCA control (DSC)

Co-Channel interference (CCI)

Interfering AP

Useful Rx Power

Min SINR to receive MCSx (sensitivity)

Co-Channel interference (CCI)

Interfering AP

Useful Rx Power

Min SINR to receive MCSx (sensitivity)

Noise floor
Rate control – DSC – mix with legacy devices

All DSC-capable STAs

DSC-capable STAs + 7 legacy STAs

No DSC

DSC

No DSC

DSC
Rate control - **TPC** – mix with legacy devices

### All TPC-capable STAs

```
No TPC  TPC
```

### TPC-capable STAs + 7 legacy STAs

```
No TPC  TPC
```
HARQ – Hybrid Automatic Repeat Request

Potential approach to improve WLAN BSS edge performance

Date: 2013-07-16

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Average Gain
Single link, single packet of 2048 bytes, CW = 32, no collisions

- Significant gain at 3dB area.
  - Higher gain for short CP in difficult channel.
- At 6dB area link adaptation works better and reduces the gain around 5%
  - Only 10% of packets being re-transmitted
- Our simulations show high gain when larger CW values are used
  - Penalty of contention becomes larger.
- In real system the channel would be many times reserved at re-transmission
  - Baseline throughput would be lower.
  - Higher relative HARQ.

Relative Gain

<table>
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<tr>
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<th>3 dB - Short CP</th>
<th>6 dB</th>
<th>6 dB - Short CP</th>
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<tr>
<td>B</td>
<td></td>
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<td>F</td>
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Gain

- 50%
- 45%
- 40%
- 35%
- 30%
- 25%
- 20%
- 15%
- 10%
- 5%
- 0%
# Full Duplex

## STR* Radios and STR* Media Access

Date: 2013-11-12

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*Simultaneous Transmit and Receive*
Third Design – Analog and Digital cancellation

- One antenna
  - Circulator
- Adaptive cancellation
  - Bank of delay lines
  - Handles frequency selective interference, isolation
- 110dB of cancellation
  - 20dBm, -90dBm noise floor
  - 80MHz @ 2.4GHz

## Massive MIMO

### Argos | Practical Massive-MIMO

- Date: 2013-11-12

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Massive MIMO test setup
Linear Gains as # AP Antennas Increases

Capacity vs. AP Antennas with 15 STAs
The latest schedule contributions
Discussion on timeline for 802.11ax

Authors:  
Date: 2014-04-17

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**Risk of a too long timeline for 802.11ax**

- If we take the example of 802.11ac to plan the timeline for 802.11ax
  - first products will reach market in 2018 and certified ones in 2019
  - there will probably be two waves of certifications as for 802.11ac

- This time-to-market is not so long for the long-term needs
  - building the Wi-Fi generation for the incoming 10 years.

- But we believe that 11ax brings improvements to Wi-Fi user experience that will be needed earlier than 2018-19
  - Looking at operators needs for carrier grade Wi-Fi
  - Looking at the growing densification and demand in public places which impacts WiFi user experience
  - Considering also alternative technologies on unlicensed bands
  - this is even more risky if we experience timeline drift as 802.11ah

→ This time-to-market is too long for these early needs
Illustration of potential timelines for 802.11ax

IEEE802.11

WFA

IEEE802.11

WFA


11ax/HEW Wave 1

11ax/HEW Wave 2

long track

fast track

11ax/HEW Wave 1

11ax/HEW Wave 2
Could Wi-Fi 2020 look like this?
### Is this your 802.11ax Wi-Fi 2020 Technology?

#### PHY
- Massive MIMO 20:20 AP
- Multi User MIMO Uplink Access
- Beam Forming w/ Interference Nulling
- Full duplex (FD) APs
- Simultaneous Dual Band
- Mobile Network Co-existence Hardening
- Enhanced Power Save for battery life

#### MAC
- Dynamic Sensitivity Control (DSC)
- HARQ w/ Soft Combining
- Legacy Protection Impact Suppression
- Control and Mgmt Frame Aggregation
- Channel Access Delay Reduction
- Dynamic Packet Flow Optimization
- SLA Performance Management

#### 802.11ax device efficiency and performance certification program

#### Customized modes:
- Ultra HD Wi-Fi
- Multimedia Wi-Fi
- Outdoor Wi-Fi
- Medical Wi-Fi

### Note: Personal sketching only, does not represent IEEE position in any manner
Thank You!

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