WiFi Training Programs

Course Outlines

Sl #	Training Topics	Training Duration (days)
1	WiFi Technology Overview	2
2	WiFi PHY and MAC Explained (upto 11ac)	3
3	WiFi 11ax Explained	2
4	WiFi Bootcamp (IP and WiFi) with hands-on	10
5	Emerging Wi-Fi Standards and Initiatives	1
6	Current Wi-Fi Status; IEEE 802.11ac and related topics	1
Module	Hands-On Packet Trace based Training Course	Duration
1	Data Transmission in Wi-Fi	3.5 Hours
2	SU Beamforming in 11ac	3.5 Hours
3	MU Beamforming/MU-MIMO in 11ac	3.5 Hours
4	WiFi Roaming and Insights on WiFi Mesh	3.5 Hours

Community Activity:

WIFi Knowledge Summit (www.wifi-ks.org): An initiative to build WiFi Community in India in partnership with academia and industry

WiFi Technology Overview – 2 days

Day-1:

Module 1: Introduction to 802.11/Wi-Fi (2 -2.5 hours)

- IEEE 802.11 and its role
- WFA and its role
- Relationship between 802.11 and Wi-Fi
- 802.11 evolution and its impacts
- Wi-Fi networks; BSS/IBSS/P2p/mesh
- BSS, IBSS, ESS, DS, BSSID, SSID
- IEEE 802.11 set of standards
- Spectrum of operation
- WLAN deployment scenarios
- Wi-Fi and IOT
- Wi-Fi and voice ; Wi-Fi calling
- Wi-Fi and LTE unlicensed
- Typical ecosystem of Wi-Fi products
- Future of Wi-Fi

Module 2: Wi-Fi PHY. Layer Technology basics (2 hours)

- Challenges; the channel environment
- Problems with high data rate communication
- Role of PHY. Layer in 802.11
- 2.4 and 5 GHz channels
- Typical Transceiver Block Diagram
- Modulation, error control coding, and interleaving
- PHY. layer technology evolution; 802.11/11b/11a/11g/11n/11ac
- Data Rates in Wi-Fi
- MIMO basics
- Spatial streams ; product and link configurations and their impacts
- Impact of MIMO
- Receive sensitivity; typical link budgets/distances for practical coverage
- PHY frame format; MPDUs to PPDU

Module 3: Medium Access Control Concepts and QoS (2-3 hours)

- Role of MAC, interactions with other layers
- Terminology ; MSDU/MPDU, header, FCS
- DCF Protocol in WLAN
- CSMA/CA – Role of PHY in CCA

- DCF parameters; DIFS/SIFS, slot time
- Basic DCF frame exchange
- Hidden node problems
- RTS/CTS/CTS-Self; virtual carrier sensing, NAV concepts
- MAC frame formats; types of frames, frame headers
- Basic DCF throughput analysis
- Efficiency enhancing mechanisms; aggregation and BACK
- Basic network operations in Wi-Fi; beacons, network entry basics
- QoS in Wi-Fi

Day-2:

Module 4: Security Concepts in WLAN (2 hours)

- Introduction to WLAN Security
  - WPA, WPA2, 802.1x, and PSK methods
  - Steps in WPA/WPA2 – PSK
  - EAP in Wi-Fi
  - Recent trends in enterprise and SoHo security
  - WPS, WIPS and WIDS systems

Module 5: Network Operations and Deployment aspects of 802.11 networks (2 hours)

- Network Entry Process – Active and Passive Scanning (will come just before security)
- Virtual APs
- Beacons in ad-hoc networks
- Evolution of power save techniques (Legacy, WMM , and SM power save)
- Rate adaptation
- 40 MHz CCA
- HT 20/40 coexistence aspects
- Protection mechanisms – motivation and operations from 802.11b/g ..802.11n)
- Impact of protection mechanisms on performance
- Typical Wi-Fi deployments and practices used by AP vendors
    - Band steering
    - Association control
    - Channel planning/Channel selection
    - AP Power and other configurations

Module 6: Understanding WiFi using MAC frames (3 hours)

- Using Wireshark for MAC frame analysis (exercises to be done by participants)
  - Basic frame exchange
  - Network entry process

    - Security parameter exchange
    - Security process exchange; PSK and EAP type; potential problems
    - 4-way handshake; deriving PTKs; potential problems
    - Roaming between APs; steps, delays, various approaches
- Performance of Wi-Fi
    - Use of tools like iperf and chariot

WiFi PHY and MAC – Explained (3 Days)

Module 1: Introduction to 802.11/Wi-Fi

- 802.11 and its role
- WFA and its role
- Differences between 802.11 and Wi-Fi
- 802.11 evolution and its impacts
- Wi-Fi networks; BSS/IBSS/P2p/mesh
- Future of Wi-Fi

Module 2: Wi-Fi PHY. Layer upto 802.11ac

- Challenges; the channel environment
- Problems with high data rate communication
- Role of PHY. Layer in 802.11
- 2.4 and 5 GHz channels ; 20 and 40 MHz bandwidth operations
- Modulation, error control coding, and interleaving
- Important PHY. Layer measurements like EVM, spectrum, and power
- PHY. layer technology evolution; 802.11/11b/11a/11g/11n
- OFDM fundamentals
- Channel models in 802.11
- OFDM in 802.11..evolution and calculations
- MIMO basics
- Spatial streams ; product and link configurations and their impacts
- Data rate calculations; different rates of operation in a Wi-Fi network
- Receive sensitivity
- PHY frame format; MPDUs to PPDU
- Role of preamble
- Role of PHY header
- HT 40 MHz preamble, greenfield concepts
- Block diagram view of a 802.11n MIMO transmitter
- SU-MIMO and MU-MIMO enhancements; Benefits
- Why beamforming, advantages of beamforming over other methods
- Feedback for beamforming; Need and Details; NDP frames
- Motivation for Mu-MIMO, link with beamforming
- MU-MIMO Group management signaling
- Impact of MU-MIMO on A-MPDU transmission in 802.11ac; QoS and BA impacts
- Benefits of MU-MIMO.. PHY. rate example
- Modulation related improvements; Challenges/transmitted power implications
- Data Rate calculations; Exercises

- 802.11ac PHY frame structure; comparisons with 802.1

Module 3: Medium Access Control Concepts-Part 1

- Role of MAC, interactions with other layers
- Terminology ; MSDU/MPDU, header, FCS
- DCF Protocol in WLAN
- CSMA/CA – Role of PHY in CCA
- DCF parameters; DIFS/SIFS, slot time
- Basic DCF frame exchange
- Hidden node problems
- RTS/CTS/CTS-Self; virtual carrier sensing, NAV concepts
- MAC frame formats; types of frames, frame headers
- Addressing in MAC frames ; use of ToDS and From DS
- Basic DCF throughput analysis; impact of headers and other overheads
- MAC layer aspects of 802.11n
    - Frame aggregation and its impact
    - A-MSDU and A-MPDU
    - TCP/IP and UDP/IP throughput impact with aggregation
    - MAC frame impacts with frame aggregation
    - Block Acknowledgement and TXoP
    - Reverse direction reservations
- Beacons in infrastructure networks
- MAC Frame analysis- use of wireshark
- Beacon frame analysis;
- RTS/CTS analysis
- Aggregation and BA frame analysis
- TCP/IP throughput in Wi-Fi- analysis of main factors
- Slow talker and its effect

Module 4: QoS in Wi-Fi

- Why QoS?
- EDCF & AC
- Block-ACK, DLS, APSD, U-APSD
- WMM and WMM-PS
- WMM Admission Control
- Voice Personal and Voice Enterprise certification programs

Module 5: Security Concepts in WLAN

- Basics of Network Security
    - Confidentiality, Integrity and Authentication
    - Security issues in wired and wireless LAN systems

- Introduction to WLAN Security
  - WEP – Encapsulation &Decapsulation
  - WPA, WPA2, 802.1x, WAPI
  - Recent trends in enterprise and SoHo security
  - WPS, WIPS and WIDS systems

Module 6: Network Operations and Deployment aspects of 802.11 networks

- Network Entry Process – Active and Passive Scanning (will come just before security)
- Virtual APs
- Beacons in ad-hoc networks
- Evolution of power save techniques (Legacy, WMM , and SM power save)
- Rate adaptation
- 40 MHz CCA
- HT 20/40 coexistence aspects
- Protection mechanisms – motivation and operations from 802.11b/g ..802.11n)
- Impact of protection mechanisms on performance

Module 7: Wi-Fi mobility, advanced MAC features

- Wi-Fi mobility handling
- IEEE 802.11r based Fast BSS Transition
- Scanning behavior of Wi-Fi devices
- IEEE 802.11k radio measurements framework
- IEEE 802.11v management and Impact on voice enterprise certification
- IEEE 802.11u and its role in public Wi-Fi
- Hotspot 2.0 and passpoint certification
- IEEE 802.11ac MAC enhancements

WiFi 802.11ax – 2 Days

Module 1: Introduction and Overview (2-3 hours)

- 802.11/Wi-Fi evolution and Status
- Real-life challenges of 802.11/Wi-Fi; high-density/large number of APs..
- Drawbacks of 802.11ac
- Motivation for 802.11ax
- New use cases
- Status of the standardization and documents
- RF bands of operation
- Competition from LTE-unlicensed (LTE-U,LAA, and MuLTEfire)
- LTE plus Wi-Fi approaches

Module 2: 802.11ax PHY (3-4 hours)

- High-level view of different PHY. modes in 11ax
- OFDM vs. OFDMA
- Concept of Rus and splits of various bandwidths
- Outdoor operation
- HE PPDU components; preambles and PHY headers
    - Backward compatible SIG field for smooth coexistence with 802.11a/g/n/ac
        - Role of R-LSIG
        - Quick and reliable 11ax PPDU detection
    - New SIG fields; HE-SIGA and HE-SIGB
        - Support of more number of STAs due to OFDMA and MU-MIMO
        - Fixed vs. variable lengths of signaling field
        - Common and user specific fields
        - Partial information
- HE PPDU Data
        - Longer OFDM Symbols – why and details
        - Guard interval options
- Handling multiple users on the DL; MU-MIMO and OFDMA
        - OFDMA and its differences with plain OFDM
        - Why OFDMA for 11ax?.
        - OFDMA details and options for different bandwidths
        - Coding and higher order modulation possibilities in 11ax

End of Day-1

Day-2

Module 3: Multiuser Operation in 802.11ax (3 hours)

- Current multiuser framework in 802.11
- Performance of 802.11 in high-density environments
- Challenges due to control and management frames
- Downlink multiuser operational details
    - Cascading operation
    - Managing ACKs/BACKs
    - MU-MIMO and OFDMA possibilities
    - UL OFDMA scheduling – trigger frames
    - MU RTS procedure
    - ACK procedure
- Uplink multiuser operations
    - UL multiuser transmission challenges
    - Trigger frames and their purpose; trigger frame format
    - UL random access
    - ACK procedure; multi-STA BA
    - Improvements in sounding protocol for beamforming
- Challenges for 11ax AP; Choice of SU vs. MU..Scheduling etc. ..

Module 4: MAC enhancements in 802.11ax (2 hours)

- CSMA/CA challenges in 802.11 in presence of multiple BSS
- Dynamic CCA Thresholds
    - Motivation
    - Approaches to solve problem
    - Coexistence challenges
- 802.11ax channel access rule
- NAV settings in 11ax
- Spatial reuse rules and impacts..
- RTS enforcement
- Multi-BSS announcement
- Trigger TWT
- New power save considerations
- New features
- Miscellaneous topics
    - CSI feedback
    - Beacon rates in 2.4 GHz
- Operation mode changes

Module 5: New WiFi Developments (2 hours)

- Multi-band Optimization and Optimized Connectivity Experience
    - Steering and managing clients
    - Load balancing and association management
    - Typical client behavior
- MBO – Motivation and some planned steps
- OCE - Use of FILS (802.11ai); cutting down initial connectivity time
- Wi-Fi Systems at home; Use of mesh, WDS, SON etc.
    - Why Wi-Fi Systems at home
    - WDS vs. mesh
    - Performance measurement of such systems a

WiFi Boot Camp – 10 Days

- Module 1: IP Networking (TCP/IP) – 3 Days
- Module 2: WiFi Technology – 7 Days

Module 1: IP Networking (TCP/IP) – 3 Days

Module 1: (day 1 – Foundation)

- Client-Server Paradigm with an application
- Addresses - IP, Domain Name, Port Number, and MAC
- Network Connectivity
- Wireshark Basics
- TCP/IP Stack/Ethernet, Encapsulation, Demultiplexing
- Network hierarchy (LAN Segment, Subnet, Net, Internet)
- Understanding the use of ARP and ARP Cache, arp utility
- Routing within Subnet and Routing in General
- Routing versus Switching
- Understanding Client-Server interaction using
  ARP, ROUTE, Tracert, PING, IPCONFIG, IPCONFIG/DNS

Module 2: (day 2 – Link and IP Layer)

- CSMACD and CSMACA Overviews
- Link Layer APIs - Developing scripts using Tcl**pcap**on top of Link layer
- Repeater, Hub as a multiport repeater,
- Bridge and Switch
- Bridge versus Switch,
- Loops and Cycles in Subnet, Spanning Tree Protocol
- Studying IP Header fields and their implications with live traffic
- IP Address Classification
- IP Header Checksum, Options
- IP Fragmentation and IP Vulnerabilities
- Overview and Details of IPv6
- ICMP

Module 3: (day 2– IP Layer and Transport Layers)

- Why Super-netting?
- IP Multicast, IP multicast with Link layer multicast demo – IGMP,DVMRP, and PIM
- UDP fundamentals

- UDP versus TCP
- Understanding TCP header and handshake using FTP &Wireshark
- TCP: Congestion Control, Flow Control, Sliding Window, Silly Window, Slow Start, etc using TTCP and Wireshark
- Hands on experiments with TCP concepts

Module 4: (day 3 – Some Core Application Layer Protocols)

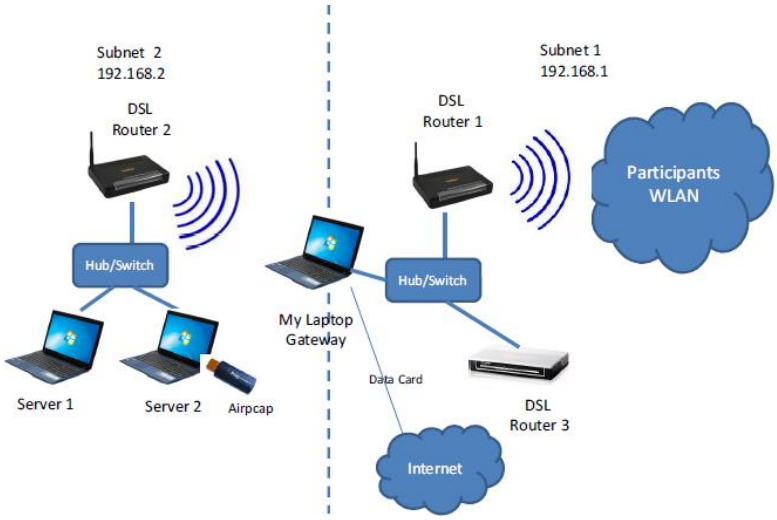
- NAT concepts
- DHCP through DHCP Server Client interaction
- BOOTP Overview

Module 5: (day 3 – VLAN and STP with PacketTracer)

- STP
- VLAN
- VLAN Trunking
- Link Aggregation and Port Aggregation
- IEEE 802.1Q, Q-in-Q, MAC-in-MAC
- VLAN Routing

Classroom Set-up Requirements:

1. LCD projector, White board, markers, etc.
2. Classroom should host *my* network (sketch below). We will bring our s/w and h/w for this network.
3. One Laptop (Windows 7 or Windows UP; No Linux) per group – 2 participants per group
4. Admin privilege required for laptops
5. Participants are required to connect to my network using their WLAN Interface
6. …



List of tentative exercises for each module:

Module 1:

1. Install Tcl, Scotty – demo simple UDP client Server
2. Show Client-Server Interaction - entities of Client-server paradigm
3. Identifying Physical Network Interfaces on your laptop
4. Checking connectivity with ping - simply identifying other options of ping for now
5. Well known Port numbers - configuration file and listing live daemons or services
6. Wireshark tutorial – Capturing, Filtering, Encapsulation, 3-main panels of Wirshark – Top panel, Encapsulation, De-Encapsulation, Multiplexing, De-multiplexing, Field Values in Raw Data.
7. Wireshark - Capturing, Marking and Saving the frames to a file, Opening and viewing pcap files
8. Identifying all addresses in Client-Server message exchange using Live messages between client-server
9. Studying ARP cache transitions with live client-server message exchange and managing ARP cache manually
10. Understanding the role of netmask with live route table
11. Exploring and drawing a sketch of classroom network

Module 2:

1. Generating and reviewing Live PPP traffic
2. Capture and review Ethernet Frame format

3. Using a simple Link Layer API for frame capture and analysis
4. Hub and Switch difference demo
5. Understanding Route Table with classroom network and live route table
6. Generating live IP fragments and understanding fragmentation fields of IP header
7. Studying some of the IP header optional fields with live packets
8. IPv6 header with IPv6 traffic

Module 3

1. UDP Traffic and reviewing Checksum
2. TCP traffic with FTP
3. Reviewing flags: SYN, ACK, RST, FIN, and URG
4. Reviewing: Sequence Number, ACK Number offset
5. Correlating Segment size with Sequence Number, ACK Number, Window Size
6. TCP Flow control with IPERF
7. Multicast traffic – relating multicast MAC with IP multicast Address
8. Studying IGMP *Membership operations*
9. SCTP handshakes and header format with SCTP Socket library
10. Streaming Audio/video Server – RTP trace

Module 4:

1. DHCP Agent, Live DHCP and BOOTP (PDU) Trace with IPCONFIG
2. NAT Address Mapping live Virtual Server

Module 5:

1. Cisco Packet Trace Tutorial
2. STP Convergence
3. Setting up VLANs
4. VLAN Trunking (Tagging)
5. Link Aggregation
6. VLAN Routing Configurations
7. RIP, OSPF

---------- 2nd Module----------

Module 2: WiFi Technology – 7 Days

Day 1

Module 1: Introduction to 802.11/Wi-Fi (3 hours)

- 802.11 and its role
- WFA and its role
- Differences between 802.11 and Wi-Fi
- 802.11 evolution and its impacts
- Wi-Fi programs and their evolution
- Wi-Fi products; from chipsets to boxes
- Future of Wi-Fi

Module 2: Wi-Fi PHY. Layer (5 hours)

- Challenges; the channel environment
- Problems with high data rate communication
- Role of PHY. Layer
- Blocks in the PHY. Layer
- Modulation, error control coding, and interleaving
- PHY. layer technology evolution
- OFDM fundamentals
- MIMO basics
- Data rate calculations; different rates of operation in a Wi-Fi network
- PHY frame format
- Role of preamble
- Role of PHY header
- Block diagram view of a 802.11n MIMO transmitter

Day 2

Module 3: Medium Access ControlConcepts-Part 1(4 hours)

- DCF Protocol in WLAN
- CSMA/CA, BEB
- RTS/CTS/CTS-Self and Fragmentation
- Inter frame spacing
- Power save operations
- MAC frame formats
- Infrastructure network operation – important aspects
- Role of Beacons
- Network entry process; active passive scanning and their performance

Lab Exercises (Basic MAC and network part) (4 hours)

- Introduction to Access Point software
  - Change in basic parameters like RTS/CTS, beacon interval and QoS Setup; typical configuration parameters

- Introduction to Wi-Fi Network analysis with wire shark

  - Wireshark and Wi-Fi
  - MAC frame analysis
  - Beacon frame analysis for 802.11b/g/n
  - NAV analysis
  - Power save message analysis

Day 3

Module 3: Medium Access Control Concepts-Part 2(4 hours)

- MAC layer aspects of 802.11n and 802.11ac
  - Frame aggregation and its impact
  - TCP/IP and UDP/IP throughput impact with aggregation
  - MAC frame impacts with frame aggregation
  - Block Acknowledgement
  - Reverse direction reservation
  - Power save aspects in 802.11n
  - Beacon Information in 802.11n

Module 4: QoS in WLAN Concepts (2 hours)

- Why QoS?
- EDCF & AC
- Block-ACK, DLS, APSD, U-APSD
- WMM and WMM-PS
- WMM Admission Control
- Voice Personal and Voice Enterprise certification programs

LAB Sessions (2 hours)

- Data rates, sizes, and signal strength analysis of different frames
- QoS analysis; beacon frames, QoS header

Day 4

Module 5: Security Concepts in WLAN and performance (4 hours)

- Basics of Network Security

- Confidentiality, Integrity and Authentication
- Security issues in wired and wireless LAN systems

- Introduction to WLAN Security
  - WEP – Encapsulation &Decapsulation
  - WPA, WPA2, 802.1x, WAPI
  - Recent trends in enterprise and SoHo security
  - WPS, WIPS and WIDS systems

Lab Sessions (4 hours)

- WPA/WPA2 home/enterprise Security setup analysis

- Performance measurement with Iperf/Jperf/chariot

  - Basics of network performance measurement
  - Measuring the impact of WI-Fi parameters on performance; QoS, congestion, RTS/CTS, aggregation, fragmentation, security, data rates, interference

Day 5

Module 6: Network Operations and Deployment aspects of 802.11 networks (4 hours)

- Virtual APs
- Beacons in ad-hoc networks
- Evolution of power save techniques (Legacy, WMM , and SM power save)
- Rate adaptation
- Protection mechanisms – motivation and operations from 802.11b/g ..802.11n)
- Impact of protection mechanisms on performance
- Enterprise deployment of 802.11n – challenges
- End to End view of 802.11 network
- Bluetooth WiFi coexistence aspects
- HT 20/40 coexistence aspects
- LTE WiFi coexistence aspects

Lab sessions (4 hours)

- Network entry analysis
- Protection analysis in different scenarios
- Impact of protection on throughput
- Going through a 802.11 specification and understanding all MAC fields

Day 6

Module 7: Upcoming 802.11Evolutions and their impacts (4hours)

- IEEE 802.11ac and its features
- IEEE 802.11ad and its features
- IEEE 802.11u and WIFi passpoint program
- IEEE 802.11r, 802.11k, 802.11w, and fast BSS transition

Lab Sessions (4 hours)

- Roaming performance analysis
- 11ac beacon analysis
- 11u beacon analysis
- 11r, 11k, and 11w frame analysis
- Going through a Wi-Fi certification plan and going through 1 specification in detail and implementing a test bed; WMM, WPA2

Day 7

Module 8: Upcoming Wi-Fi certification programs and deployment aspects (4hours)

- Wi-Fi Miracast, IBSS,
- Wi-Fi home deployment features
- Wi-Fi enterprise deployment; controllers and their features, cloud based operations
- Wi-Fi Hotspot deployment
- Wi-Fi cellular interaction

Summary, Review and overall exam and analysis of questions (4 hours)

Exams and test

- All modules will have an informal quiz in a Jeopardy style format to encourage participation from all.
- A concept quiz covering all topics on WLAN will be given at the end.
- All lab exercises will have questions to be filled in by the attendees.

Classroom Set-up Requirements for hand-son exercise:

- Laptop with Sniffer enabled for live capture (AirPcap adapters would be preferred).
- Wireshark for analysing captured frames. Chariot and omnipeekto be provided by Atheros team
- 1 AP for a group to configure and capture sniffer outputs

Emerging Wi-Fi Standards and Initiatives – 1 Day

IEEE 802.11ac

- Motivation
- Project goals
- RF bands of operation
- New features; PHY layer
- Higher bandwidths
- SU-MIMO and MU-MIMO enhancements
- Modulation related improvements
- Data Rate calculations
- 802.11ac PHY frame structure
- RTS/CTS based bandwidth signaling
- PHY. Layer differences/improvements over 802.11n
- MAC layer differences/enhancements over 802.11n
- 802.11ac deployment aspects; backhaul and other challenges

Upcoming 802.11/WiFi Evolutions

- IEEE 802.11ad and its features
    - Bands of Operation
    - Technology Basics – Beam forming
    - Data rates and application initiatives – Wireless HDMI
- IEEE 802.11u and WiFi passpoint program
    - Wi-Fi cellular Interaction – Motivation
    - 802.11u based Hotspot 2.0 spec
    - 3GPP initiatives
- IEEE 802.11r, 802.11k, 802.11v,802.11w
    - Fast BSS Transition Overview
    - 802.11r based roaming
    - Radio measurements using 802.11k
    - 802.11v based management
    - 802.11w based management frame security
- Wi-Fi Miracast, IBSS, and TDLS
    - Wi-Fi Display Basics
    - TDLS motivation and advantages
        - IEEE 802.11ah – Low Power sub 1 GHz Wi-Fi and other 802.11 programs

Current Wi-Fi Status; IEEE 802.11ac and related topics (1 day)

- Wi-Fi market recap; growth of Wi-Fi
- Current retail and enterprise trends in Wi-Fi; mesh/repeater/extender Wi-Fi and the related challenges

802.11ac technology

- RF bands of operation
- New features; PHY layer
- Higher bandwidths; challenges, advantages; contiguous and non-contiguous bonding
- Dynamic bandwidth usage in 802.11ac; Signaling of bandwidth and use of VHT frames in different bandwidth scenarios; conceptual view of 802.11ac transceiver implementation
- Range and power implications with higher bandwidth usage
- MIMO Review and MIMO terminology
- SU-MIMO and MU-MIMO enhancements; Benefits
- Why beamforming, advantages of beamforming over other methods
- Feedback for beamforming; Need and Details; NDP frames
- Motivation for Mu-MIMO, link with beamforming
- MU-MIMO Group management signaling
- Impact of MU-MIMO on A-MPDU transmission in 802.11ac; QoS and BA impacts
- Benefis of MU-MIMO.. PHY. rate example
- Modulation related improvements; Challenges/transmitted power implications
- Data Rate calculations; Exercises
- 802.11ac PHY frame structure; comparisons with 802.11n
- VHT fields like PAID, MU-MIMO related VHT-SIGB
- VHT-LTFs, cyclic shifts, beam forming indication, analysis of cases with different PHY. Features.
- PHY frame format nuances with MU-MIMO transmissions
- MAC layer differences/enhancements over 802.11n; A-MPDU formats
- Why only A-MPDUs in 802.11ac?
- Power save implications due to long A-MPDU transmissions
- 802.11ac deployment aspects; backhaul and other challenges; certification evolution
- 802.11ac packet trace based exercises

Understanding 802.11/Wi-Fi through packet analysis

The modules in this course are designed to explore 802.11/ Wi-Fi through packets. A brief recap of the relevant protocol aspects for a given module will be given at the start. Participants can pick and choose modules and the learning objectives shall be met only by completing the exercise which will be done as a part of the class. Wireshark or Omnipeek or any other equivalent tool can be used for the analysis of traces which will be given for each exercise. Each module will have sufficient theory relevant to the module with atleast 1 exercise to be done by the participants in the class.

Module 1: Data Transmission in WiFi (3.5 hours)

- Quick recap of Wi-Fi protocol and capabilities understanding
- Data frames addressing
  - Source/transmit and destination/receive addressing
- QoS Control field analysis; A-MSDU and TID info.
  - QoS data type
  - A-MSDU insights
  - QoS access category
- A-MPDU aspects in the trace; how to infer?
  - Why is A-MPDU analysis important
  - Impact of frame sizes
- Block ACK analysis
  - BA bitmap
- Retransmissions monitoring
  - How can we debug potential Wi-Fi performance problems?.
- MIMO; spatial streams, STBC, antennas etc.
- Use of RTS/CTS
- Power save in Wi-Fi; use of null frames

Module 2: SU Beamforming in 11ac (3.5 hours)

Conceptual background of SU Beamforming (1 hour)

- Spatial streams, space-time streams, number of antennas; what is the difference?
- Some product configurations and their interpretations
- Beamforming basics
- NDP announcement and NDP; conceptual overview
- SU Beamforming operations
- Potential challenges; what is 11ax doing in this area?

Trace based analysis of Beamforming (2 hours)

- Basic wireshark analysis of 802.11
- How to look at PHY. Related information, MCS, rates, beamforming, bandwidth etc.
- AP and client support for beamforming; where to find out?
- Beamforming example; starting from Sounding to data transmission
- Potential problem scenarios; where could things go wrong?

Module 3: MU Beamforming/ MU-MIMO in 11ac (3.5 hours)

Conceptual background of MU Beamforming (2 hours)

- Beamforming basics; Differences between SU and MU Beamforming/terminology
- Some product configurations and their interpretations
- NDP announcement and NDP; Differences with SU case
- MU Beamforming
- Potential challenges; 11ax improvements

Trace based analysis of Beamforming (1.5 hours)

- AP and client support for beamforming ; where to find out?; specifically MU Beamforming
- MU Beamforming example; starting from Sounding to data transmission
- Potential problem scenarios; where could things go wrong in MU Beamforming?
- Real-life performance impacts of MU Beamforming

Module 4: Wi-Fi Roaming and insights on Wi-Fi meshes (3.5 hours)

Wi-Fi Roaming (2.5 hours)

- Wi-Fi roaming without 11r
- 802.11r basics
- Trace analysis with and without 11r
    - 11r related capabilities exchange
    - Different keys and their roles
- Use of 11k and its impacts
    - 11k related capabilities
    - Neighbour request messages
- 11v BSS Transition management and its impacts
    - 11v capabilities

- Roaming delay calculations

Wi-Fi mesh/repeaters/extenders concepts (1 hour)

- Why Wi-Fi meshes/repeaters/extenders?
- Various approaches followed in practice ; use of 2-radio and 3-radio solutions
- Differences between Wi-Fi mesh and other approaches
- Throughput impacts
- Roaming/band steering/ measurements/band steering etc.