

Wi-Fi Technology Fundamentals



WI-FI TECHNOLOGY
FUNDAMENTALS COURSE

Module-1
Introduction and History of WiFi
Session-1a

Wi-Fi Evolution

Pyramid of Basic Human Needs

Self- Realization

Self-esteem

Friends, Family

Safety, Security

Food, Water, Shelter

Wi-Fi



Course Objective

While most technology courses may take a bottom up academic approach of explaining the subject matter with definitions and formulas, the attempt of this course would be to explain all the concepts in as simple and as practical way as possible by providing real work examples and industry applications and showing real demos and visualizations of the concepts where ever possible. Our goal with this course is to make the complex world of WiFi easy to understand for beginners and also hopefully generate more interest among young engineers and college students to build a successful career in this amazing and rapidly growing field of WiFi.

Who is this course for?

- Junior/Mid-Level engineers working in any form of technical roles in the WiFi Industry
- Bachelors/Masters Degree students pursuing a career in the computer networking / wireless networking industry
- Academicians interested in developing industry focused course work.

Pre-requisites

- Basics of Computer Networking, Any prior academic courses or certifications like CCNA
- Nice to have basic understanding of wireless communications, Digital Communications.
- Nice to have some prior academic knowledge of WiFi standards and protocols or have some industry experience and a WiFi developer or test engineer.

What Does each Session Cover

- Basic theoretical concepts of each topic.
- Real-world / Industry applications of the topic.
- Practical Demos of the concepts of each topic using any tools available.
- A short fun quiz at the end of each session.
- Each session is expected to be 45min-60mins of duration.

Course Fees and Copyright Policy

- This course is completely free for anyone attending. The material can also be downloaded and can be used for free.
- Several images in the presentations will be copied from the internet and books and credit will be given to the source of the information wherever possible.
- The presenter does not intend to use this material for any commercial purposes.

Course Delivery

- The course is entirely delivered online over web conferencing sessions.
- The meeting links and calendar invites will be shared ahead of time.

Instructor Bio



Sitarama Penumetsa

CTO, Candela Technologies Inc.

GM, Candela Technologies India Pvt Ltd

Email: sitarama@candelatech.com

Sitarama Penumetsa has 23 years of academic, research and Industry experience in the field of WiFi. Starting his career as junior researcher in WLAN standards and moving onto becoming a Subject Matter Expert, Sitarama developed a strong interest and deep knowledge in WiFi technology.

Transitioning to the Industry, Sitarama started as a software developer of WLAN test solutions and over the past 20 years, moved on to Technical Marketing, Project Management, Business Development roles which allowed him to work with over 100 companies worldwide building products in the field of WiFi and through this he developed deep understanding of the industry applications and ecosystem of WiFi Technology.

Sitarama also has the experience of conducting several WiFi technology training sessions, bootcamps, seminars etc...to his colleagues and team members in the industry over the years and through this processed developed and updated lots of training material in the field of WiFi.

Sitarama currently serves as the CTO of Candela Technologies and also heads the India division of the same company.

Module 1: Introduction and History of WiFi	
Week1	Session1a: Evolution of WiFi WiFi Generations, Residential WiFi Applications, Enterprise WiFi Applications, Business Evolution
	Session1b: WiFi Network Topologies Infrastructure/Mesh/Bridge/Adhoc Modes, Various Backhaul Mechanisms, Various Deployment Use cases
Week2	Session1c: WLAN Standards and Amendments Alphabet Soup IEEE Standards Bodies, WiFi Alliance, Standards and their extensions
	Session1d: Basic Functional building blocks of a WiFi AP/Router PHY, Baseband, Lower MAC, Upper MAC, various Interfaces, key functional blocks
Module 2: WLAN PHY Layer	
Week3	Session2a: Frequency Allocation ISM and UNII Bands, unlicensed spectrum allocation, channels, Channel BW
	Session2b: Modulation/Coding, MIMO Basics Basics of Digital Modulation and Coding, Multipath, MIMO, OFDMA, Spectral Efficiency
Week4	Session2c: MCS Table, PHY Data Rates PHY Data rates, MCS Table, Theoretical Throughput
	Session2d: PHY Headers and key functions PHY Headers, PCLP and PMD Sub Layers, Key PHY later functions
Module 3: WLAN MAC Layer	
Week5	Session3a: Basic AP Management and Control Functions Beaconing, BSSID, Scanning, Basic Service Set and its Capabilities
	Session3b: MAC Framing, Headers and Key Functions MAC headers and key functions, Management/Control/Data Frames
Week6	Session3c: Carrier Sense and Medium Access Physical/Virtual Carrier Sensing, DCF, Random Backoff, Interframe Spacing, EDCA Parameters
	Session3d: Basic connection and Data Transfer Basic Client Connection, BSS Capabilities, Data Transfer Mechanism, Aggregation, Rate Adaptation

Module 4: Security in WiFi	
Week7	Session4a: Various WiFi Security Protocols WEP, WPA/WPA2, Enterprise/Personal, Radius, Captive Portal, WPS,
	Session4b: Basics of Authentication and Encryption EAP Methods, TKIP/CCMP, 802.1x connection, Key Generations, 4-way Handshake
Week8	Session4c: Attacks and Vulnerabilities DoS Attacks, Man in the Middle Attacks, Cracking Security Keys, PMF
	Session4d: Seamless connectivity/OpenRoaming OpenRoaming Technology, WiFi to Cellular Handover, EAP-SIM/AKA
Module 5: Other Advanced Topics	
Week9	Session5a: WLAN AP/Controller Architectures Thick AP, Thin AP models, Physical Controller, Cloud Controller
	Session5b: RRM, QoS, Mobility, Power Save Load Balancing, Band Steering, ACS, DFS, TPC, Various Roaming Techniques, Legacy/WMM Power Save
Week10	Session5c: WiFi6 new features ODFMA, Mu-MIMO, BSS Coloring, 1024 QAM, WPA3
	Session5d: WiFi6E new features 6GHz spectrum allocation, 320Mhz channels, AFC
Week11	Session5e: WiFi7 new features 4K QAM, MLO, Preamble Puncturing
	Session5f: Smart WiFi Features Traffic Shaping/Policing, Parental Controls, Advanced Analytics, AI/ML
Week12	Session5g: WiFi Mesh Networks Mesh Topologies, Various deployment models, Mesh Access/Backhaul/Roaming
	Session5i: WiFi Monetization Location Based Analytics, WiFi Sensing, Information Technology to Operational Technology
Module6: Troubleshooting and Tools	
Week13	Session6a: Wireshark Capture Analysis Wireshark WLAN filters, Radio tap headers, Information Element Analysis, I/O Charts
	Session6b: Basic test/debug/spectrum analysis tools iPerf, Ping, WiFi scanner tools, Kali Linux tools, Site Survey/Planning Tools, Heatmapping Tools
Week14	Session6c: Suppliant logs, AP logs, basic debug commands APIs and Interfaces to AP config, Serial/Telnet/restAPIs, Supplicant and AP debug logs

How to Stay Connected?

Access Course Webpage



[Click here: Wi-Fi Technology Fundamentals Course \(candelatech.com\)](https://candelatech.com)

- ✓ Access course notes, slides, video recordings

Register to Get Updates



[Click Here: Registration \(zoho.in\)](https://zoho.in)

- ✓ Provide basic contact info to get calendar invites, reminders and updates about the material and sessions.

Join Whatsapp Group



[Click here: WhatsApp Group Invite](#)

- ✓ Provide basic contact info to get whatsapp messages about calendar invites, reminders and updates about the material and sessions.

Registration Breakdown

Profession	Percentage
Working Professionals	56%
Students	27%
Unknown	16%
Faculty	1%

Work Exp	Percentage
0 - 1 years	53%
1 - 4 Years	25%
4 - 10 years	16%
10+ years	6%

Majority of Registrants:

- Junior Engineers from India
- Engineering Students from India

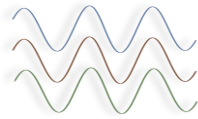


Country	Percent
INDIA	84.8%
USA	4.4%
UK	1.7%
THAILAND	1.5%
BRAZIL	1.3%
RUSSIA	1.1%
TURKEY	0.8%
AUSTRALIA	0.7%
CANADA	0.3%
EGYPT	0.3%
GERMANY	0.3%
PAKISTAN	0.3%
FRANCE	0.2%
INDONESIA	0.2%
UAE	0.2%
ALGERIA	0.1%
BELGIUM	0.1%
CHILE	0.1%
IRAN	0.1%
JAPAN	0.1%
KENYA	0.1%
MALAYSIA	0.1%
PANAMA	0.1%
PERU	0.1%
PHILIPPINES	0.1%
PORTUGAL	0.1%
SOUTH AFRICA	0.1%
SRI LANKA	0.1%
SWEDEN	0.1%
TUNISIA	0.1%
YEMEN	0.1%



Module-1
Introduction and History of WiFi
Session-1a
Wi-Fi Evolution

20 Years of WiFi Success Story



1985 JUNK BANDS

The FCC makes an unprecedented move, opening up three spectrum bands for unlicensed use anyone who follows the rules can use them. This spectrum was previously used for government radar.

FCC, 2002



1990 WIRELESS PAYMENTS INTRODUCED

WaveLAN, an early version of Wi-Fi, is installed in cash registers a critical first step for digital payments and the wireless economy

EE Times, 2015

1994 Wi-Fi GOES TO COLLEGE

Carnegie Mellon University begins installing the first campus-wide Wi-Fi network.

Carnegie Mellon
University, 2011



2007 BUSINESS ESSENTIAL

Laptops replace Desktops as the go-to work computer, making Wi-Fi a critical business technology

IHS Markit, 2008

1999 LOOK MA, NO WIRES!

Steve Jobs unveils Apple's iBook, the first commercial laptop able to surf web wirelessly.

Cult of Mac, 2016



2010 TABLETS

Wi-Fi-only tablets were introduced, setting off the global mobile computing revolution in homes, offices and businesses.

Fast Company, 2010



2017 NEW REALITIES

The first self-contained virtual reality headset launches, powered entirely by Wi-Fi.

Oculus, 2019

2022

5G Speeds FOR BILLIONS WITH Wi-Fi

Wi-Fi 6 global annual chipset shipments will exceed 1 billion.

ABI Research, 2018

EVEN MORE Wi-Fi

57% of internet traffic will run over Wi-Fi,

Cisco, 2018

1985 FROM TRASH TO LITTLE TREASURES

This spectrum is almost immediately put to use for home appliances like microwaves, garage door openers and baby monitors

FCC OET Working
Paper, 2003



1988-1989 WIRELESS ROUTERS ARRIVE

The first wireless routers, the Proxim 900 MHz RangeLAN and ARLAN-SST. Were specialty devices to connect computers in warehouses and track retail inventories

IEEE, 2008

1991 CUTTING THE CORD

Vtech releases the first 900 MHz cordless phone using the former junk spectrum

Chicago Tribune,
1993



1997 A NEW STANDARD

The first set of standards for Wi-Fi the IEEE 802.11 protocol is released. It carries data at 2MB/S

The Verge, 2019

2005 MILLIONS SOLD

More than 120 million Wi-Fi chipsets shipped.

Wi-Fi Alliance,
2005



2008 SMART PHONES

Apple's iPhone 3G launches with Wi-Fi, kicking off the smartphone era and a boom in Wi-Fi devices and traffic.

Apple, 2008

2015 BILLION SOLD

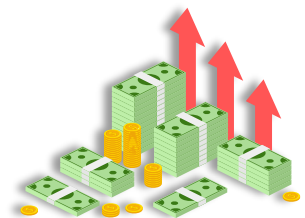
10 billion Wi-Fi devices have been sold, from cell phones to tablets to sensors at rail yards and wireless airport gates operations to medical telemetry units and point of sale devices in retail stores, Wi-Fi powers our daily lives

Wi-Fi Alliance,
Jan 2015

2018 Wi-Fi SUPERCHARGES THE ECONOMY

Wi-Fi generated more than \$500 billion in economy value in the United States

WifiForward, 2018



2023 SPOILER: THIS WILL BE BIG

Wi-Fi is expected to generate nearly \$1 trillion for the U.S. economy in 2023

Wi-Fi Alliance, 2018

Some Initial WiFi Hardware



(a)

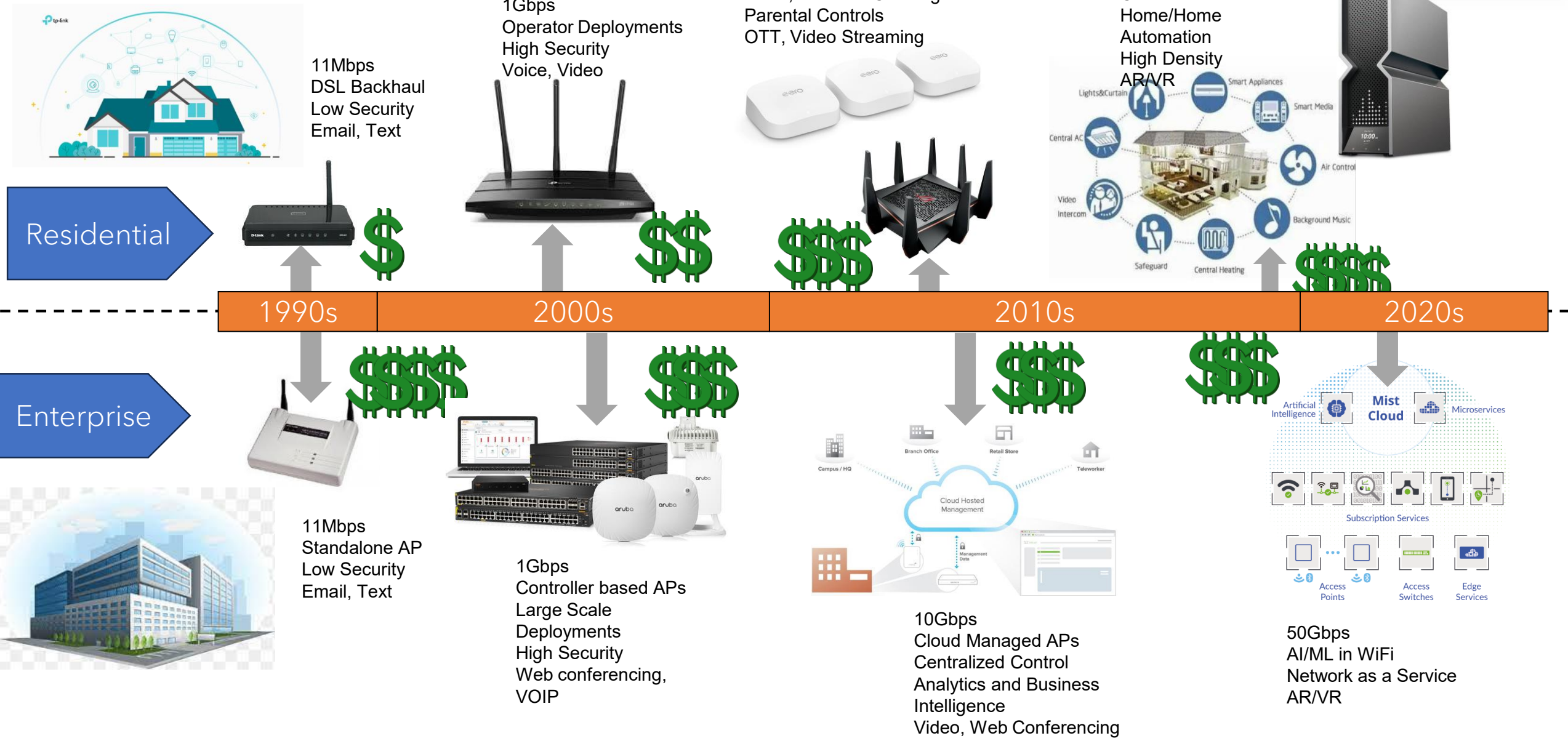


(b)



a Some historical pioneering shoe box size WLANS designed by Motorola, Persoft, Aironet, and WINDATA, **b** the wireless PC cards and its access points in Roamabout designed by Digital Equipment Corporation

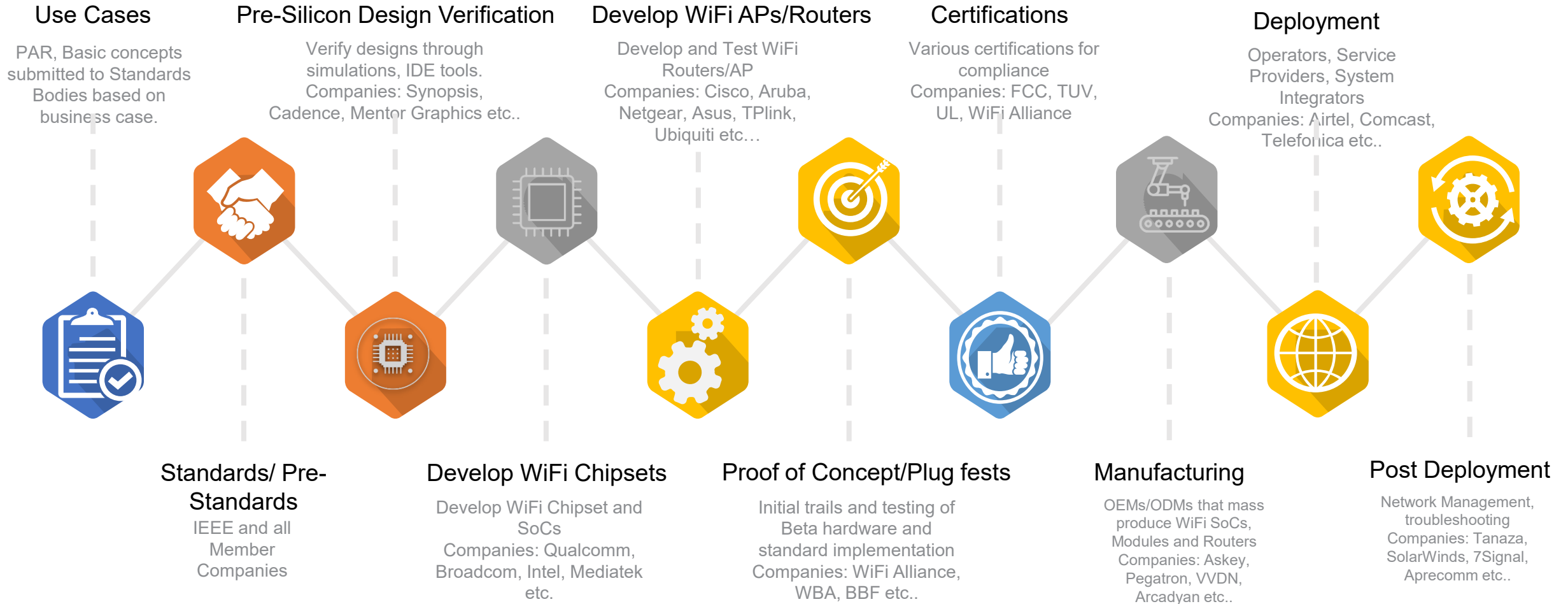
WiFi Technology Evolution (Hardware to Software)



WiFi in Key Industries



WiFi Technology Life Cycle / Industry Ecosystem



WiFi Devices

Home



- ✓ Gaming Devices
- ✓ Camera
- ✓ Printer
- ✓ Home Media Server
- ✓ Set-top Box
- ✓ Wireless TV
- ✓ Refrigerator
- ✓ Oven
- ✓ Washer/Dryer
- ✓ Vacuum Cleaner
- ✓ Light bulbs
- ✓ Security systems
- ✓ Digital Photo Frames
- ✓ Home Robot

Healthcare



- ✓ Patient Monitor
- ✓ Infusion Pump
- ✓ Defibrillator
- ✓ Weigh Machine
- ✓ Asset Tracking
- ✓ Blood Pressure Machine

Retail/Industrial



- ✓ Printer
- ✓ Scanner
- ✓ POS
- ✓ Warehouse equipment
- ✓ Shipping lines
- ✓ Asset Tracking
- ✓ Industrial Robots
- ✓ Power Meters
- ✓ Surveillance
- ✓ Temp Pressure Monitoring Systems

Transportation



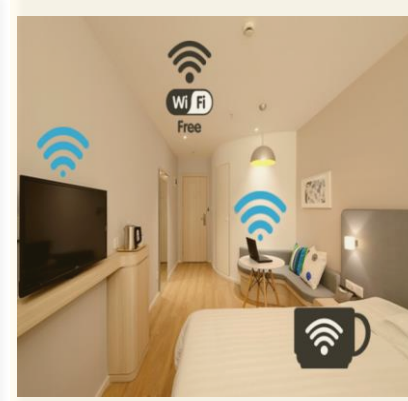
- ✓ Trains
- ✓ Planes
- ✓ Ships
- ✓ Cars
- ✓ Drones

Enterprise



- ✓ Laptops
- ✓ Smartphones
- ✓ Tablets
- ✓ Video conferencing Devices
- ✓ Surveillance
- ✓ Digital Whiteboards

Hospitality



- ✓ Wireless TVs
- ✓ Digital Tables
- ✓ Rental Cars

WiFi Technology Generations

	Wi-Fi 4 (IEEE 802.11n)	Wi-Fi 5 (IEEE 802.11ac)	Wi-Fi 6 (IEEE 802.11ax)	Wi-Fi 6E (IEEE 802.11ax)	Wi-Fi 7 (IEEE 802.11be)
Frequency bands operations	2.4GHz (2.402 - 2.494) 5GHz (5.030 - 5.990)	5GHz (5.030 - 5.990)	2.4GHz (2.402 - 2.494) 5GHz (5.030 - 5.990)	2.4GHz (2.402 - 2.494) 5GHz (5.030 - 5.990) 6GHz (5.925 7.125)	2.4GHz (2.402 - 2.494) 5GHz (5.030 - 5.990) 6GHz (5.925 7.125)
Maximum bandwidth per channel	2.4GHz: 40MHz 5GHz: 40MHz	2.4GHz: 40MHz 5GHz: 80MHz	2.4GHz: 40MHz 5GHz: 160MHz	2.4GHz: 40MHz 5GHz: 160MHz 6GHz: 160MHz	2.4GHz: 40MHz 5GHz: 160MHz 6GHz: 320MHz
Maximum number of non-overlapping channels	2.4GHz: 3 Channel:1,6,11	5GHz: Channels:36,52 (80MHz)	2.4GHz: 2 (40MHz) Channel:1,11 5GHz: Channel 36: 5.180 GHz to 5.340 GHz (160 MHz width) or Channel:36,52,100,116,132(80 MHz)	2.4GHz: 2 (40MHz) Channel:1,5,9,13 5GHz: Channel 36: 5.180 GHz to 5.340 GHz (160 MHz width) Channel 36,52,100,116,132 (80MHz) 6GHz: 7 (160MHz)	2.4GHz: Channel 1,5,9,13 (40MHz) 5GHz: 2 (160MHz) or Channel 36,149 (80MHz) 6GHz: Channel 31, 63, 95, 127, 159, 191 (320MHz)
Maximum MIMO configuration	4x4	4x4	8x8	8x8	16x16
Highest modulation	64 QAM	256 QAM	1024 QAM (1K QAM)	1024 QAM (1K QAM)	4096 QAM (4K QAM)
Maximum PHY datarate	600 Mbps	1.73 Gbps	9.6 Gbps	9.6 Gbps	46.1 Gbps
Multi user MIMO (MU-MIMO)	N/A	Downlink (Wave 2 only)	Downlink Uplink	Downlink Uplink	Downlink Uplink
Multi user OFDMA (bandwidth sharing)	N/A	N/A	Yes	Yes	Yes
Target Wake Time (TWT)	N/A	N/A	Yes	Yes	Yes (improved)
Multi Link Operation / Multi Resource Unit	N/A	N/A	N/A	N/A	Yes

Why WiFi Technology is so successful?



Low Cost

Extremely low cost of installation (CAPEX) and maintenance (OPEX) when compared to cellular



IP Network Compatible

A seamless network edge extension of the ubiquitous IP networking.



Uses Unlicensed Spectrum

Use of Unlicensed spectrum significantly decrease barriers for entry.



High Data Rates

Extremely high data rates for short/medium range fixed wireless when compared to all other technologies



Enterprise Grade Security

Full enterprise grade security, seamless mobility, excellent user/policy/network management.



Easy to Deploy

No heavy equipment of infrastructure needed. Easy to install both indoor and outdoor when compared to cellular



Scalability

Can scale to 1000s of Access Points and lots of users and can be managed from single dashboard



Open Technology

WLAN standards are designed to be open , giving implementors a lot of flexibility to customize for applications.

Some References

Evolution and Impact of Wi-Fi Technology and Applications: A Historical Perspective

<https://link.springer.com/article/10.1007/s10776-020-00501-8>

The Evolution of Wi-Fi networks: from IEEE 802.11 to Wi-Fi 6E

<https://www.wevolver.com/article/the-evolution-of-wi-fi-networks-from-ieee-80211-to-wi-fi-6e>

The Evolution of Wi-Fi Technology and Standards

<https://standards.ieee.org/beyond-standards/the-evolution-of-wi-fi-technology-and-standards/>

Beyond Everywhere : *How Wi-Fi became the world's most beloved*

<https://www.gregennis.net/> *technology*

The Wi-Fi Evolution An integral part of the wireless landscape

https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/Web_WiFi_Evolution_Tech_Exe_04022013.pdf

Steve Jobs introduces WiFi to the masses with a hula hoop!

<https://www.youtube.com/watch?v=HFngngjy4fk>



QUIZ!

TIME