

Application of WiFi in bridging the digital divide in developing countries

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History of WiFi

- WiFi stands for Wireless Fidelity protocol. The Institute of Electrical and Electronic Engineers (IEEE) first introduced standard No 802.11 in 1997.
- The protocol defined three physical layers in the 2.4 GHz and 5.8 GHz frequency band:
 - **Direct Sequence Spread Spectrum (DSSP) at 1 Mbps**
 - **Frequency Hopping Spread Spectrum (FHSS) at 2 Mbps**
 - **Infrared (IR)**

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2.IEEE Standards

- In 1999 the first standard was ratified by IEEE to create two new standards:
 - 802.11a: Orthogonal Frequency Division Multiplexing (OFDM) was added in the 5 GHz spectrum with transmission speeds of up to 54 Mbps
 - 802.11b: was added 5.5 and 11 mbps support using DSSS in the 2.4 GHz making it backward compatible with 802.11 (1 and 2 Mbps) DSS gear
- In 2003 the second standard was ratified to create 802.11g
 - 802.11g: high speed transmission up to 54 mbps by applying OFDM in the 2.4 GHz unlicensed spectrum.
 - The 802.11g is backward compatible with 802.11b by integrating DSSS modulation techniques at 11, 5.5, 2 and 1 Mbps.

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2.1 IEEE 802.11a Standard:

- The 802.11a standard defined 54 mbps wireless system at 5.8 GHz with 12 non-overlapping channels.
- The systems using this standard have a lower range compared to 802.11b.
- The advantage is that the systems are less prone to electromagnetic interference from other cordless devices.
- These systems can be used for
 - building to building and for
 - backhaul applications where there is line of Sight.
- The disadvantages of 802.11a are those of short range and higher cost compared to 802.11b systems.

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802.11a Channel Numbering

Channel	Center freq.(MHz)
36	5180
40	5200
48	5240
52	5260
56	5280
60	5300
64	5320
149	5745
153	5765
157	5785
161	5805

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2.2 IEEE 802.11b Standard:

- The 802.11b systems are manufactured for use in the 2.4 GHz ISM band with 11 non-overlapping channels.
- The range of the systems varies depending on the transmitter power and antenna gain.
- The maximum transmission speed is 11 Mbps auto negotiable down to rates of 5.5, 2 and 1 Mbps as the signal strength deteriorates.
 - The advantages of 802.11b systems are:
 - » (a) high range and
 - » (b) less expensive

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802.11b channels:

Ch Number	Center Freq. MHz
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452
10	2457
11	2462
12	2467
13	2472
14	2484

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2.3 IEEE 802.11g Standard

- **IEEE 802.11g standard defines systems that are made to OFDM and DSSS modulation technology in the 2.4 GHz with a maximum transmission speed of 54 Mbps.**
- **These systems are normally used as repeaters and backhaul applications.**
- **The systems are backward compatible with 802.11b equipment. 802.11g have only three non-overlapping channels**

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3. FCC Regulations for use of WiFi

- **FCC stands for Federal Communication Commission (USA)**
- **802.11 requirements:**
 - Operates in the unlicensed spectrum- Industrial, Scientific and Medical (ISM) band
 - No monthly or yearly service fee in USA
 - Not free from regulation

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Unlicensed Bands

- ISM Bands: Industrial Scientific & Medical
 - 902 to 928 MHz
 - 2400 to 2485 MHz
 - 5725 to 5850 MHz

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3.2 Unlicensed National Information Infrastructure (U-NII Bands):

- 5150 to 5250 MHz up to 50 milli Watt transmit power (40 mW IEEE)
- 5250 to 5350 MHz up to 250 milli Watt transmit power (250 mW, IEEE)
 - These bands are designed for wireless data networking and internet to schools in USA.

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3.3 FCC Rules: EIRP Limits for WiFi

- (a) Point to Point systems in the 2.4 to 2.5 Ghz: 36 dBm (4 Watts)
- (b) Point to multipoint in the 2.4 to 2.5 Ghz: 30 dBm (1 watt)
- © For every 3 dBi of antenna gain over 6dBi, the transmitter output power must be reduced by 1 dB

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Link Budget

- Transmitter power + Transmit antenna gain + Receive antenna gain + Receiver gain - Free Space Loss (FSL)

Whereby:

- $FSL = 20 * \log_{10} (F/MHz) + 20 \log_{10} (D/Miles) + 36.6$
- $Fresnel\ Zone = 72.1 * \sqrt{D1 * D2 / F\ GHz} * D$
- $Link\ Margin = (RSL - RX\ Sensitivity)\ dB\ or\ SNR$

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Link calculation

- Here is a simple table of path loss calculations in free space for channel 1 with clear line of sight (the difference in path loss from channel 1 to channel 11 is negligible).
- Distances are in miles;
- losses are in dB.

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Path calculation table

• Distance (miles)	Losses Ch 1 dB
0.5	98
1	104
2	110
3	114
4	116
5	118
7	121
10	124
15	128
20	130
25	132
25	134

» $L = 20 \log(d) + 20 \log(f) + 36.6$

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4. WiFi Networking

- **Can be used to bridge missing links in access networks and trunk networks in rural and suburban areas**
- **Can be offered as a free internet service in hotels, airports, cafes, universities (hot spots)**
- **Can attract new customers for ISPs and Data Operators**
- **Are relatively cheap compared to traditional microwave systems**
- **Offer high speed and bandwidths**
- **Can provide data and voice services where there is no telecom presence**

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Advantages of WiFi

- **No license fees**
- **Easy to install**
- **Secure air interface**
- **Higher level encryption software on the APs and server**
- **Host based firewalls for APs and client PCs**
- **Antivirus bundles**
- **Anti spyware applications**
- **Up to date patches**

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Network Modes:

- **Adhoc mode or peer to peer mode:**
 - In this mode there is no Access Point in the network. It is also called Independent basic Services Set (IBSS). All client devices communicate directly with each other
- **Infrastructure mode:**
 - In this mode all client devices communicate with each other via an Access Point -The AP is connected to a wired infrastructure e.g a DSL. This type of network is also called Basic Service set (BSS).

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Components of WiFi Network

Access Points

- » Off the shelf single board embedded computers
- » Run on Windows or Linux

- **Wireless Client Devices**

- Notebook computers
- PCMCIA cards
- Mini PCI Cards without integrated antennas
- Desktop PCs
- PCI Cards with integrated antennas
- USB devices for desktop PCs
- Wireless Ethernet bridge
- PDAs
- Compact Flash Cards & Secure digital IO cards

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Case Study/applications:

- WiFi based Wireless Internet Infrastructure
- WiFi for high speed data transmission at 5, 11,54 ,108 Mbps
- WiFi for mobile backhaul
- WiFi for Internet to schools
- WiFi for Telemedicine
- WiFi for community networks
- WiFi for hot spots in hotels, Airports etc
- WiFi for Campus WANs

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WiFi Internet Infrastructure

- WiFi (Wireless Fidelity) is basically a generic term for wireless LAN equipments, also known as WLAN. It normally conforms the standard IEEE 802.11 family and, thus, supported by many vendors.
- Why WiFi based Wireless Internet Infrastructure? There are few simple answers, i.e:
 - Wireless for bypassing the need of costly & slow telephone line for accessing the Internet.
 - Wireless is easy to deploy.
 - It requires a much lower cost in the long run, rather than rely on Telco's infrastructure.
 - WiFi is basically a Wireless LAN and, thus, it runs at higher speed 1-11Mbps if the standard IEEE 802.11b is used.
 - Since IEEE 802.11b is an open standard, WiFi equipments can be obtained easily in the market. Today, it costs only about 3-4 times a UTP LAN cards & going down.
 - Having last mile telecommunication infrastructure solved, next best thing to do is sharing the access to the surrounding neighborhood & share the access fee to reduce the cost per subscribers.²²

Example of WiFi Link

- **WiFi link Trieste to Muggia across the Adriatic Channel in Italy**
 - **Link distance; 25 Kilometers**
 - **Transmitter Power: 25 dB**
 - **Antenna gain: 23 dB**
 - **Link speed: 11 mbps**
 - **Equipment used : Metrix Radio**
 - **Total Link cost: US \$ 5000**

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Some of the Basic Assumptions

- **Knowing that WiFi equipment has a limited communication range about 5-8 km due to its low power, some basic assumptions imposed, e.g.,**
- **It is basically to by pass last mile Telco infrastructure, about 5-8 km distance.**
- **The Access Point may be located at Internet Service Provider (ISP).**
- **As for the Internet Service Provider (ISP), their Internet links may use different telecommunication media especially for long distance links. Some of the examples as**
 - **Optical fiber.**
 - **Microwave links.**
 - **VSAT links.**

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Price Estimate of A WiFi System

- **Access Point** **US\$62-130**
- **Pigtail** **US\$30**
- **Coax** **US\$90-130**
- **Sectoral Antenna** **US\$500-800**
- **Omni Antenna** **US\$150-240**
- **Total Investment** **US\$330-1100**

WiFi Alliance

A society of wireless industry

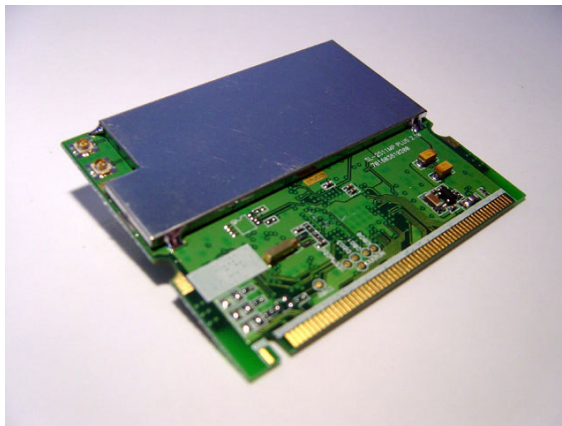
– Functions:

- performs interoperability tests on 802.11 equipment before issuing WiFi trademark
- serves as non-profit industry advocate
- gives assurance to consumers that an Access Point (a) purchased from one manufacturer will work with a PCMCIA card from another manufacturer

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WiFi Radio card

- Embedded pc



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WiFi Radio opened

- Radio



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Power over Ethernet

- Ethernet power adapter



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Outdoor Enclosures

- Radio enclosure



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Complete radio kit



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WiFi products

- More radio cards



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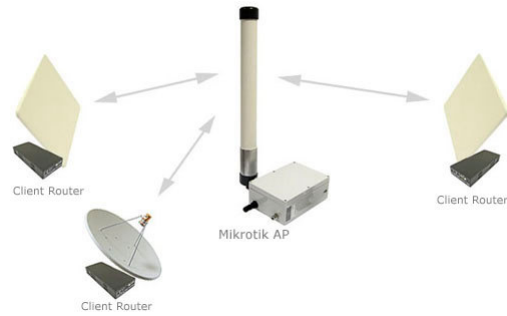
Access Point



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Point to multipoint WiFi

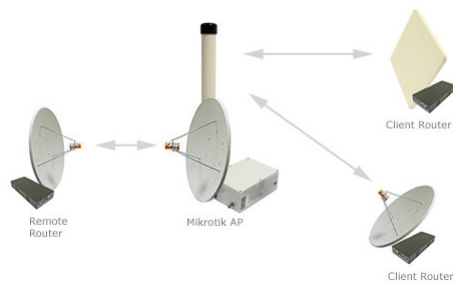
- **Access Point**



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WiFi as backbone

- **Backbone link**



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Access Points

Wireless 2.4GHz (802.11b) Router

DI-514

Up to 11Mbps and fully compatible with 802.11b*



Tri-Mode Dualband 802.11a/b/g (2.4/5GHz) Wireless 108Mbps* Router

DI-784

Up to 108Mbps and fully compatible with 802.11a/b/g*



High-Speed 2.4GHz (802.11g) Wireless Router

DI-524

Fully compatible with 802.11b



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Way Forward & Conclusions

- WiFi systems are useful for providing connectivity in rural and sub-urban areas where there is lack of access for Internet and data.
- WiFi networks can be rapidly deployed in Africa
- WiFi systems are cheap compared to traditional digital radio systems
- WiFi systems use license free bandwidths in the 2.4 and 5.8 Ghz for high speed data communication for communities, schools, health care, research and scientific applications
- WiFi systems can bridge the missing digital link for the user and the service provider
- The regulators should not stop communities and scientists from using WiFi to communicate where there is no other means of communication
- Operators could consider using WiFi for network deployments

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