9. Conclusion

This research was able to uncover the acute importance of formulating a new regulatory policy regime for the effective use of 2.4 GHz and 5 GHz frequency bands for the development of IT sector in Sri Lanka. Although certain regulatory provisions are in place, it has been demonstrated that they may not be conducive to economic and technological advancement of the country.

It is revealed that Internationally, several countries have introduced necessary amendments to the respective telecommunications regulatory frame works in a timely and sensible manner taking into consideration of the local needs and global developments in the IT industry.

Based on international situations it is evident that regulatory frameworks for various IT related applications in these bands have been formulated under two basic usage categories such as low power indoor and high power outdoor. This categorization is further justified by the stakeholders in the local environment as most of their views were expressed under similar setup. Hence it is recommended to formulate the Sri Lankan regulatory frame work for IT based applications in 2.4 GHz and 5 GHz bands under low power indoor and high power outdoor usage categories.

Low Power Indoor Usage

While analyzing the local situation, it is revealed that there is a huge potential for low power IT related wireless applications which would facilitate in house broadband data and Internet requirements. Further, as per the views expressed by the stakeholders, it is evident that there is a greater need to consider all low power applications in these frequency bands under licence exempted category. In order to meet this pressing demand, it is extremely important to eliminate certain regulatory restrictions which are currently in place due to some legislative reasons.

The traditional logic that exclusive frequency licences are needed to manage interference, has been significantly undermined due to technological advancement. Internationally many countries have successfully introduced this unlcenced model into practice in wireless environment for several years. However these unlicenced applications are subject to certain technical and operational limitations. Internationally most of the regulators have authorized maximum power levels in the range of 100-200 mW e.i.r.p. and the applications are limited to indoor use. Most of the regulators have introduced such technical and operational limitations as this power level is sufficient for majority of the indoor applications and further at this power level two close by independent networks can be operated simultaneously without causing interference to each other.

In the above context following recommendations are made for the efficient and effective utilization of 2.4 GHz and 5 GHz frequency bands under low power indoor usage category.

Frequency bands	-	2400 – 2483.5 MHz (ISM Band) 5150 – 5350 MHz 5470 – 5725 MHz 5725 – 5875 MHz (ISM Band)
Maximum Power allowed	-	200 mW e.i.r.p.
Usage restriction	-	Public and private networks Indoor use only – (localized onsite use)
Licensing Requirement	-	Licence Exempted

Currently usage of equipment under this category is not licence exempted. As a result there is a practical difficulty in implementing this proposal. However, even at present certain category of applications such as cellular phones and subscriber terminals of WLL PSTN Operators' are exempted from annual charges through a Gazette Notification and hence no licences are issued for such applications. As an immediate short term solution, it is recommended that a similar procedure could be implemented. ie; to exempt this category of equipment from annual frequency charges through a Government Gazette Notification.

However, necessary amendments to the Telecommunication Act should be introduced so that the Telecommunications Regulatory Commission is empowered with required legal authority to declare licence exempted applications when necessary, considering the national interest/requirements of the country. It should be noted that this process can not be implemented within a short time period.

High Power Outdoor Usage

In developed countries nationwide reliable telecommunication delivery platforms such as copper and fiber are in place for the provision of public telecommunication services. However in most of these countries outdoor unlicensed broadband networks are in place as an alternative to the high cost reliable telecom networks. In developing countries like Sri Lanka, considering the socio economic situation of the country, it is very unlikely that public telecom Operators would invest in high cost telecommunication networks even to provide services in significant parts of the country. Hence, the only option available in developing countries to provide public telecommunication services is to rely on cost effective wireless solutions.

In the above context, it is the responsibility of the government to provide access to reliable national resources such as radio frequency spectrum, at a reasonable cost to the public telecom Operators in order to promote IT and telecom industry in the country. It is very important that the radio spectrum available for such public networks be maintained with adequate protection from interference as otherwise Operators may reluctant to invest on it. Hence, for outdoor applications the most appropriate arrangement for Sri Lankan environment would be, a limited number of Operators with shared access rights to the spectrum.

According to the views expressed by several category of stakeholders such as, PSTN Operators, FBDOs, ISPs etc. it is evident that there is an imperative requirement to have a reliable, interference free wireless media for the Operators to deploy their public networks through out the country. Hence in order to preserve the reliability of the wireless access media, authorization should be limited to certain number of users.

In the above context, considering technical parameters/requirements identified in the global scene and the present and future demand of IT related applications in Sri Lanka, following regulatory arrangements are recommended under outdoor usage category.

Telecommunication System Licence (Section 17 Licence) be issued to limited number of Operators for setting up of infrastructure facilities for the provision of public data and Internet related services. The frequency usage is authorized on shared basis to those licenced Operators and subsequently, Operators should obtain a Spectrum Licence (Section 22 Licence) for the usage of frequencies, which should be annually renewable.

Frequency band	-	2400 – 2483.5 MHz (ISM Band) 5250 – 5350 MHz 5470 – 5725 MHz
Maximum power allowed	-	1000 mW e.i.r.p.
Frequency band	-	5725 – 5875 MHz (ISM Band)
Maximum power allowed	-	2000 mW e.i.r.p.
Usage restriction	-	Public networks, Outdoor use

2.4 GHz Band

Currently the entire 2.4 GHz band is not available for data and Internet related applications. Hence considering the international situation as well as the national requirements immediate, action should be taken by TRC to vacate present occupants in the frequency band 2.43-2.50 GHz.

Proposed actions to vacate the occupants in the 2.4 GHz band are,

i. Alternative frequency bands should be identified for Sri Lanka Telecom Ltd., Airport and Aviation Ltd., Multivision Pvt Ltd. for their present operations in this frequency band.

ii. In case of Multivision Pvt. Ltd., as there are altogether eighteen (18) frequency channels assigned for the MMDS service in 2.4 - 2.7 GHz range, they should be advised to operate only within the balance thirteen (13) channels which fall outside the 2.4 GHz ISM band. Further they should be encouraged to use digital technology instead of present analog technology, so that radio spectrum could be utilized more effectively and more television channels could be accommodated within the said 13 frequency channels.

iii. Due prior notice should be given (at least two to three years) to the present occupants to vacate the band and if necessary to migrate to alternative frequency bands, there by Regulatory Commission can get away from paying any compensation due to immediate clearance of the band.

Considering the present allocations made in this band, it is not advisable to authorize the usage of 2.4 GHz band for any new users for outdoor high power applications without clearing the band as even at present the existing FBDOs are experiencing severe practical difficulties due to bandwidth restrictions. This situation may aggravate if new users are authorized even within the 30 MHz allocated for data services. However, once the entire 2.4 GHz ISM band is cleared, it should be considered for new users in selected geographical areas specially in outside western province.

5 GHz Bands

In Sri Lanka, the 5 GHz bands are not allocated for any service yet. According to the international situations, it has been proved that these bands are ideally suitable for outdoor broadband applications.

According to the IEEE standards, in 5 GHz bands the number of non-overlapping channels available with a bandwidth of 20 MHz is shown in the **Table (9-a)**. Which means in any given location similar number of carriers can be operated simultaneously without causing interference to each other.

Frequency Band (MHz)	Number of Non-overlapping Channels
5250 - 5350	4
5470 - 5725	11
5725 - 5875	6

Table (9-a) – Number of Non-overlapping Channels in 5 GHz Bands

In order to allow several users to access the radio spectrum, specially in rural areas, it is recommended that certain portion of spectrum should be allocated on provincial basis in addition to the island-wide allocations. In this arrangement if any Operator needs to deploy it's network only in specific area such requirements can be accommodated effectively.

In the above context following options are recommended for the allocation of 5 GHz spectrum;

Option I

All three bands are allocated for licenced Operators on shared basis and the usage of spectrum should be limited to that particular band by each Operator. Number of Operators in each band is shown in the **Table (9-b)** on island wide and Provincial basis. The total number of Operators in any given area is identical to number of non-overlapping channels available in each band as illustrated in **Table (9-a).**

Frequency Band (MHz)	Number of Operators	
	Island-wide	Per Province
5250 - 5350	2	2
5470 - 5725	5	5
5725 - 5875	3	3

Table (9-b) – Proposed Number of Operators in 5GHz Band – Option I

Option II

All three bands are allocated for licenced Operators and each Operator should be authorized to use all three bands on shared basis. This option gives the freedom to the Operator to select any frequency band depending on the geographical location. The proposed number of Operators on island-wide and provincial basis is shown in **Table (9-c)** below. The number of Operators proposed is based on the total number of non-overlapping channels available in three bands as shown in **Table (9-a)**.

Frequency Band (MHz)	Number of Operators	
	Island-wide	Per Province
5250 - 5350 5470 - 5725 5725 - 5875	10	10

Table (9-C) – Proposed Number of Operators in 5GHz Band – Option II

As per the views expressed by some of the stakeholders it is evident that there is a greater demand to setup private wireless networks in specific outdoor environments such as Universities, Community Centers etc. Hence it is recommended that the 5 GHz ISM band (5725-5875 MHz) be allocated for such applications under licence exempted category as this is the most commonly used un-licenced band through out the world. However operations within this un-licenced band should be subjected to the technical limitations specified above.

Option III

Outdoor operations are permitted to authorized licenced Operators only in first two bands and allocation of spectrum will be made proportionately as per either Option I or Option II. The number of Operators related to two options are shown in **Table(9-d)** and **Table (9-e)**.

The frequency band 5725-5875 MHz (ISM Band) will be treated as un-licenced band. Any individual user will get the opportunity to utilize this band to setup outdoor private networks subject to same technical limitations as specified under high power outdoor category and no licence is required to operate within this band.

Option III-a

Frequency Band (MHz)	Number of Operators	
	Island-wide	Per Province
5250 - 5350	2	2
5470 - 5725	5	5
5725 - 5875	Private Usage	Un-licenced

Table (9-d) – Proposed Number of Operators in 5GHz Band

Option III-b

Frequency Band (MHz)	Number of Operators	
	Island-wide	Per Province
5250 - 5350 5470 - 5725	7	7
5725 - 5875	Private Usage	Un-licenced

Table (9-e) – Proposed Number of Operators in 5GHz Band

According to the discussions had with the different category of stakeholders, it is very evident that there is a huge potential to introduce new IT based products and services in Sri Lankan economy. It is the responsibility of the government to identify the prime needs of different stakeholders and to make every efforts to fulfill their requirements. The radio frequency spectrum is treated as one of the valuable national resource in present day IT industry. Hence the effective utilization of radio spectrum is of very vital importance for the development of IT industry in Sri Lanka.

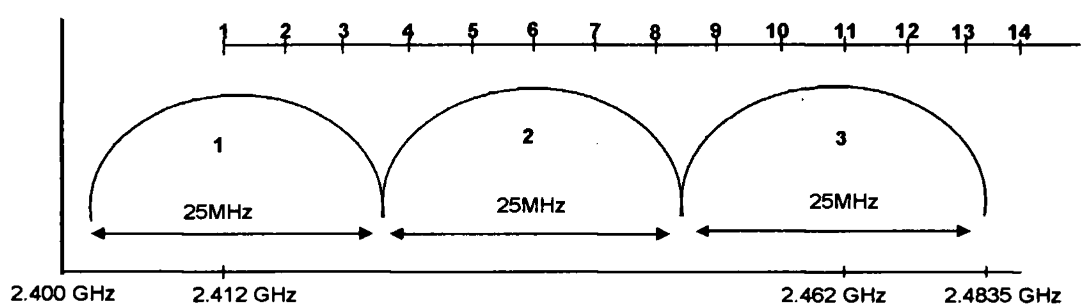
APPENDIX A

Channel arrangement in IEEE 802.11b and IEEE 802.11g standards

Any installation of 802.11b of 802.11g devices comprising an access point with its associated nodes uses only a portion of the 83.5 MHz (2400 – 2483.5MHz) of spectrum available in the 2.4 GHz band. An access point and its associated devices occupy a single radio channel using approximately 25 MHz of the 83.5 MHz available . Therefore in any location , no more than three access points (25 MHz x 3) can operate without interfering with each other. Channels with full separation in frequency are referred to as **non-overlapping channels** as illustrated in **Figure(A-I).**

The 802.11b and 802.11g standards do allow nearby access points to use channels whose centres are separated by less than 25 MHz such that their channel usage partially overlaps. In the United States , an access point can be configured using one 11 centre frequencies. Europe allow use of up to 13 centre frequencies and Japan up to 14. Centre frequencies of the 802.11 b and 802.11g standards are shown in **Table (A-I)**. Use of more than three of the allowed centre frequencies in any location will result in reduced performance due to interference between nearby access points. There are maximum of three non-overlapping channels available in the 2.4 GHz band in the United States, Europe , Japan and in most of the other countries. Typically, channels 1, 6 and 11 are used as the three non – overlapping channels.

Allowed Centre Frequencies



Figure(A-I) Non- Overlapping Channels in 2.4 GHz Band

(Source – Athores Communications, 2003)

Operating Channel Number	Channel Centre Frequency (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	2477

Table (A-I) - Channel Numbers and Center frequencies in 802.11 b/802.11g Standards

(Source – IEEE)

APPENDIX-B

Decision of WRC-2003 on 5GHz Frequency Allocation for RLAN and Wireless Access Systems

Frequency Allocation and Foot Notes

Region 1	Region 2	Region 3
5 150-5 250	AERONAUTICAL RADIONAVIGATION FIXED-SATELLITE (Earth-to-space) 5.447A **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD03** 5.446 5.447 5.447B 5.447C	
5 250-5 255	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH 5.447D **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD04** 5.448 5.448A **ADD 5.BD01**	
5 255- 5 350	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH (active) **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD04** 5.448 5.448A **ADD 5.BD01**	
5 470-5 570	MARITIME RADIONAVIGATION **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD07** EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION **ADD 5.BD06** 5.450 5.451 5.452 5.448B	
5 570-5 650	MARITIME RADIONAVIGATION **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD07** RADIOLOCATION **ADD 5.BD06** 5.450 5.451 5.452	
5 650-5 725	RADIOLOCATION **MOBILE except aeronautical mobile ADD 5.BD02 ADD 5.BD07** Amateur Space research (deep space) 5.282 5.451 5.453 5.454 5.455	

Table (B-I) - International Frequency Allocation Table for 5GHz Band

(Source – ITU Final Acts, 2003)

5.BD01 *Additional allocation:* The band 5 250-5 350 MHz is also allocated to the fixed service on a primary basis in the following countries in Region 3: Australia, Korea (Rep. of), India, Indonesia, Iran (Islamic Republic of), Japan, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand and Viet Nam. The use of this band by the fixed service is intended for the implementation of fixed wireless access (FWA) systems and shall comply with Recommendation ITU-R F.1613. In addition, the fixed service shall not claim protection from the radiodetermination, Earth exploration-satellite (active) and space research (active) services, but the provisions of No. **5.43A** do not apply to the fixed service with respect to the Earth exploration-satellite (active) and space research (active) services. After implementation of FWA systems in the fixed service with protection for the existing radiodetermination systems, no more stringent constraints should be imposed on the FWA systems by future radiodetermination implementations. (WRC-03)

5.BD02 The use of the bands 5 150-5 350 MHz and 5 470-5 725 MHz by the stations in the mobile service shall be in accordance with Resolution **[COM5/16] (WRC-03)**. (WRC-03)

5.BD03 In the band 5 150-5 250 MHz, stations in the mobile service shall not claim protection from earth stations in the fixed-satellite service. Number **5.43A** does not apply to the mobile service with respect to FSS earth stations. (WRC-03)

5.BD04 In the band 5 250-5 350 MHz, stations in the mobile service shall not claim protection from the radiolocation service, the Earth exploration-satellite service (active) and the space research service (active). These services shall not impose on the mobile service more stringent protection criteria, based on system characteristics and interference criteria, than those stated in Recommendations ITU-R M.1638 and ITU-R SA.1632. (WRC-03)

5.BD06 In the frequency band 5 470-5 650 MHz, stations in the radiolocation service, except ground-based radars used for meteorological purposes in the band 5 600-5 650 MHz, shall not cause harmful interference to, nor claim protection from, radar systems in the maritime radionavigation service. (WRC-03)

5.BD07 In the band 5 470-5 725 MHz, stations in the mobile service shall not claim protection from radiodetermination services. Radiodetermination services shall not impose on the mobile service more stringent protection criteria, based on system characteristics and interference criteria, than those stated in Recommendation ITU-R M.1638. (WRC-03)

RESOLUTION [COM5/16] (WRC-03)

Use of the bands 5 150-5 250, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks

The World Radio communication Conference (Geneva, 2003),

considering

a) that this Conference has allocated the bands 5 150-5 350 MHz and 5 470-5 725 MHz on a primary basis to the mobile service for the implementation of wireless access systems (WAS), including radio local area networks (RLANs);

b) that this Conference has decided to make an additional primary allocation for the Earth exploration-satellite service (EESS) (active) in the band 5 460-5 570 MHz and space research service (SRS) (active) in the band 5 350-5 570 MHz;

c) that this Conference has decided to upgrade the radiolocation service to a primary status in the 5 350-5 650 MHz band;

d) that the band 5 150-5 250 MHz is allocated worldwide on a primary basis to the fixed-satellite service (FSS) (Earth-to-space), this allocation being limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service (No. **5.447A**);

e) that the band 5 150-5 250 MHz is also allocated to the mobile service, on a primary basis, in some countries (No. **5.447**) subject to agreement obtained under

No. **9.21**;*f)* that the band 5 250-5 460 MHz is allocated to the Earth exploration-satellite service (EESS) (active) and the band 5 250-5 350 MHz to the space research service (active) on a primary basis;

g) that the band 5 250-5 725 MHz is allocated on a primary basis to the radiodetermination service;

h) that there is a need to protect the existing primary services in the 5 150-5 350 and 5 470-5 725 MHz bands;

i) that results of studies in ITU-R indicate that sharing in the band 5 150-5 250 MHz between WAS, including RLANs, and the FSS is feasible under specified conditions;

j) that studies have shown that sharing between the radiodetermination and mobile services in the bands 5 250-5 350 and 5 470-5 725 MHz is only possible with the application of mitigation techniques such as dynamic frequency selection;

k) that there is a need to specify an appropriate e.i.r.p. limit and, where necessary, operational restrictions for WAS, including RLANs, in the mobile service in the bands 5 250-5 350 MHz and 5 470-5 570 MHz in order to protect systems in the Earth exploration-satellite service (active) and space research service (active);

l) that the deployment density of WAS, including RLANs, will depend on a number of factors including intrasystem interference and the availability of other competing technologies and services,

further considering

a) that the interference from a single WAS, including RLANs, complying with the operational restrictions under *resolves* 2 will not on its own cause any unacceptable interference to FSS receivers on board satellites in the band 5 150-5 250 MHz;

b) that such FSS satellite receivers may experience an unacceptable effect due to the aggregate interference from these WAS, including RLANs, especially in the case of a prolific growth in the number of these systems;

c) that the aggregate effect on FSS satellite receivers will be due to the global deployment of WAS, including RLANs, and it may not be possible for administrations to determine the location of the source of the interference and the number of WAS, including RLANs, in operation simultaneously,

noting

that, prior to WRC-03, a number of administrations have developed regulations to permit indoor and outdoor WAS, including RLANs, to operate in the various bands under consideration in this Resolution,

recognizing

a) that in the band 5 600-5 650 MHz, ground-based meteorological radars are extensively deployed and support critical national weather services, according to footnote No. **5.452**;

b) that the means to measure or calculate the aggregate pfd level at FSS satellite receivers specified in Recommendation ITU-R S.1426 are currently under study;

c) that certain parameters contained in Recommendation ITU-R M.1454 related to the calculation of the number of RLANs tolerable by FSS satellite receivers operating in the band 5 150-5 250 MHz require further study;

d) that the performance and interference criteria of spaceborne active sensors in the Earth exploration-satellite service (EESS) (active) are given in Recommendation ITU-R SA.1166;

e) that a mitigation technique to protect radiodetermination systems is given in Recommendation ITU-R M.1652;

f) that an aggregate pfd level has been developed in Recommendation ITU-R S.1426 for the protection of FSS satellite receivers in the 5 150-5 250 MHz band;

g) that Recommendation ITU-R SA.1632 identifies a suitable set of constraints for WAS, including RLANs, in order to protect the EESS (active) in the 5 250-5 350 MHz band;

h) that Recommendation ITU-R M.1653 identifies the conditions for sharing between WAS, including RLANs, and the EESS (active) in the 5 470-5 570 MHz band;

i) that the stations in the mobile service should also be designed to provide, on average, a near-uniform spread of the loading of the spectrum used by stations across the band or bands in use to improve sharing with satellite services;

j) that WAS, including RLANs, provide effective broadband solutions;

k) that there is a need for administrations to ensure that WAS, including RLANs, meet the required mitigation techniques, for example, through equipment or standards compliance procedures,

resolves

1 that the use of these bands by the mobile service will be for the implementation of WAS, including RLANs, as described in Recommendation ITU-R M.1450;

2 that in the band 5 150-5 250 MHz, stations in the mobile service shall be restricted to indoor use with a maximum mean e.i.r.p.[1] of 200 mW and a maximum mean e.i.r.p. density of 10 mW/MHz in any 1 MHz band or equivalently 0.25 mW/25 kHz in any 25 kHz band;

3 that administrations may monitor whether the aggregate pfd levels given in Recommendation ITU-R S.1426[2] have been, or will be exceeded in the future, in order to enable a future competent conference to take appropriate action;

4 that in the band 5 250-5 350 MHz, stations in the mobile service shall be limited to a maximum mean e.i.r.p. of 200 mW and a maximum mean e.i.r.p. density of 10 mW/MHz in any 1 MHz band. Administrations are requested to take appropriate measures that will result in the predominant number of stations in the mobile service being operated in an indoor environment. Furthermore, stations in the mobile service that are permitted to be used either indoors or outdoors may

---

[1] In the context of this Resolution, "mean e.i.r.p." refers to the e.i.r.p. during the transmission burst which corresponds to the highest power, if power control is implemented.

[2] $-124 - 20 \log_{10} (h_{SAT}/1\,414)$ dB(W/(m^2 · 1 MHz)), or equivalently,
$-140 - 20 \log_{10} (h_{SAT}/1\,414)$ dB(W/(m^2 · 25 kHz)), at the FSS satellite orbit,
where h_{SAT} is the altitude of the satellite (km).

operate up to a maximum mean e.i.r.p. of 1 W and a maximum mean e.i.r.p. density of 50 mW/MHz in any 1 MHz band, and, when operating above a mean e.i.r.p. of 200 mW, these stations shall comply with the following e.i.r.p. elevation angle mask where θ is the angle above the local horizontal plane (of the Earth):

-13	dB(W/MHz)	for $0° \le \theta < 8°$
$-13 - 0.716(\theta-8)$	dB(W/MHz)	for $8° \le \theta < 40°$
$-35.9 - 1.22(\theta-40)$	dB(W/MHz)	for $40° \le \theta \le 45°$
-42	dB(W/MHz)	for $45° < \theta$;

5. that administrations may exercise some flexibility in adopting other mitigation techniques, provided that they develop national regulations to meet their obligations to achieve an equivalent level of protection to the ESSS(active) and SRS (active) based on their system characteristics and interference criteria as stated in Recommendation ITU-R SA.1632;

APPENDIX C
Channel Arrangement in 5GHz Bands

The 802.11a standard accommodates up to 24 non-overlapping channels in the 5 GHz bands.

Channel Numbering

The set of valid operating channels in various countries is defined by the respective regulatory authorities. Channel center frequencies are defined at every integral multiple of 5 MHz above 5 GHz. The relationship between center frequency and channel number is given by the following equation.

Channel center frequency = 5000 + 5 x Nch (MHz)
Where Nch - 0, 1, 2,..........200

This definition provides a unique numbering system for all channels with 5 MHz spacing from 5 GHz to 6 GHz and the flexibility to define channelization sets for all current and future regulatory domains.The set of valid operating channel numbers and centre frequencies for 802.11a standard is shown in **Table (C-I).**

Frequency Band	Operating Channel Number	Channel Centre Frequency (MHz)
5.15 – 5.25 GHz	36	5180
	40	5200
	44	5220
	48	5240
5.25 – 5.35 GHz	52	5260
	56	5280
	60	5300
	64	5320
5.47-5.725 GHz	100	5500
	104	5520
	108	5540
	112	5560
	116	5580
	120	5600
	124	5620
	128	5640
	132	5660
	136	5680
	140	5700
5.725 – 5.825 GHz	149	5745
	153	5765
	157	5785
	161	5805

Table (C-I) - Channel Numbers and Center Frequencies in 802.11a Standard
(Source – IEEE)

APPENDIX D

IEEE 802.11b Wireless LAN Standard

IEEE 802.11 standard specifies a 2.4 GHz operating frequency with data rates of 1 and 2 Mbps using either direct sequence (DSSS) or frequency hopping spread spectrum (FHSS). IEEE 802.11b data is encoded using DSSS (Direct Sequence Spread Spectrum) technology. DSSS works by taking a data stream of zeros and ones and modulating it with a second pattern, the chipping sequence.

In 802.11, that sequence is known as the Barker code, which is an 11-bit sequence (10110111000) that has certain mathematical properties making it ideal for modulating radio waves. The basic data stream is XOR'd with the Barker code to generate a series of data objects called chips. Each bit is "encoded" by the 11 bit Barker code, and each group of 11 chips encodes one bit of data.

The CCK (Complementary Code Keying) achieves 11 Mbps. Rather than using the Barker code, CCK uses a series of codes called Complementary Sequences. Because there are 64 unique code words that can be used to encode the signal, up to 6 bits can be represented by any one particular code word (instead of the 1 bit represented by a Barker symbol).

The wireless radio generates a 2.4 GHz carrier wave (2.4 to 2.483 GHz) and modulates that wave using a variety of techniques. For 1 Mbps transmission, BPSK (Binary Phase Shift Keying) is used (one phase shift for each bit). To accomplish 2 Mbps transmission, QPSK (Quadrature Phase Shift Keying) is used. QPSK uses four rotations (0, 90, 180 and 270 degrees) to encode 2 bits of information in the same space as BPSK encodes 1. The trade-off is increase power or decrease range to maintain signal quality. Because the FCC regulates output power of portable radios to 1 watt e.i.r.p. (equivalent isotropic radiated power), range is the only remaining factor that can change. On 802.11 devices, as the transceiver moves away from the radio, the radio adapts and uses a less complex (and slower) encoding mechanism to send data.

The MAC layer communicates with the PLCP via specific primitives through a PHY service access point. When the MAC layer instructs, the PLCP prepares MPDUs for transmission. The PLCP also delivers incoming frames from the wireless medium to the MAC layer. The PLCP sublayer minimizes the dependence of the MAC layer on the PMD sublayer by mapping MPDUs into a frame format suitable for transmission by the PMD.

Under the direction of the PLCP, the PMD provides actual transmission and reception of PHY entities between two stations through the wireless medium. To provide this service, the PMD interfaces directly with the air medium and provides modulation and demodulation of the frame transmissions. The PLCP and PMD communicate using service primitives to govern the transmission and reception functions.

The CCK code word is modulated with the QPSK technology used in 2 Mbps wireless DSSS radios. This allows for an additional 2 bits of information to be encoded in each symbol. Eight chips are sent for each 6 bits, but each symbol encodes 8 bits because of the QPSK modulation. The spectrum math for 1 Mbps transmission works out as 11 Mchips per second times 2 MHz equals 22 MHz of spectrum. Likewise, at 2 Mbps, 2 bits per symbol are modulated with QPSK, 11 Mchips per second, and thus have 22 MHz of spectrum. To send 11 Mbps 22MHz of frequency spectrum is needed.

It is much more difficult to discern which of the 64 code words is coming across the airwaves, because of the complex encoding. Furthermore, the radio receiver design is significantly more difficult. In fact, while a 1 Mbps or 2 Mbps radio has one correlator (the device responsible for lining up the various signals bouncing around and turning them into a bit stream), the 11 Mbps radio must have 64 such devices.

Figure (D-I) shows the digital modulation of data with PRN sequence.

Figure (D-II) shows the Modified Walsh Transform uses for the reception of DSSS signal

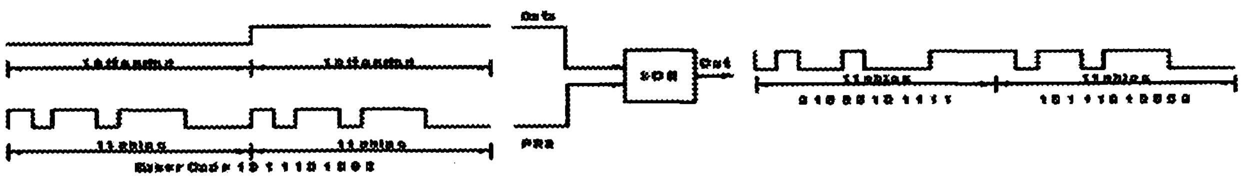


Figure (D-I)- Digital Modulation of Data with PRN sequence

(Source –Vocal Technologies Ltd.)

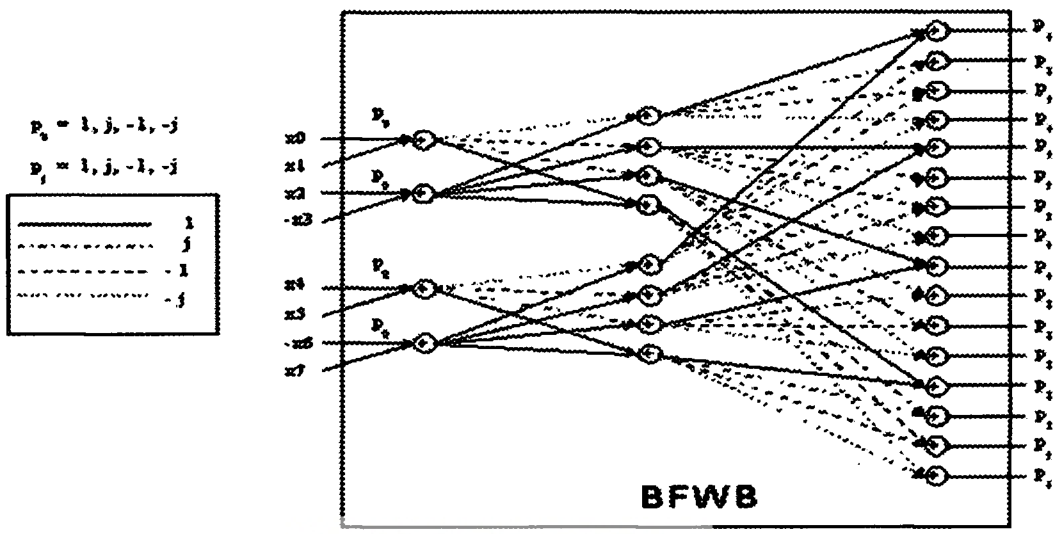


Figure (D-II)- Modified Fast Walsh Transform

(Source –Vocal Technologies Ltd.)

The wireless physical layer is split into two parts, called the PLCP (Physical Layer Convergence Protocol) and the PMD (Physical Medium Dependent) sub-layer. The PMD takes care of the wireless encoding explained above. The PLCP presents a common interface for higher-level drivers to write to and provides carrier sense and CCA (Clear Channel Assessment), which is the signal that the MAC (Media Access Control) layer needs so it can determine whether the medium is currently in use.

The PLCP consists of a 144 bits preamble that is used for synchronization to determine radio gain and to establish CCA. The preamble comprises 128 bits of synchronization, followed by a 16 bits field consisting of the pattern 1111001110100000. This sequence is used to mark the start of every frame and is called the SFD (Start Frame Delimiter).

The next 48 bits are collectively known as the PLCP header. The header contains four fields: signal, service, length and HEC (header error check). The signal field indicates how fast the payload will be transmitted (1, 2, 5.5 or 11 Mbps). The service field is reserved for future use. The length field indicates the length of the ensuing payload, and the HEC is a 16 bits CRC of the 48 bits header.

In a wireless environment, the PLCP is always transmitted at 1 Mbps. Thus, 24 bytes of each packet are sent at 1 Mbps. The PLCP introduces 24 bytes of overhead into each wireless Ethernet packet before we even start talking about where the packet is going. Ethernet introduces only 8 bytes of data. Because the 192 bits header payload is transmitted at 1 Mbps, 802.11b is at best only 85 percent efficient at the physical layer.

APPENDIX E

IEEE 802.11a Wireless LAN Standard

The IEEE 802.11a standard specifies an OFDM physical layer (PHY) that splits an information signal across 52 separate sub-carriers to provide transmission of data at a rate of 6, 9, 12, 18, 24, 36, 48, or 54 Mbps. The 6, 12, and 24 Mbps data rates are mandatory. Four of the sub-carriers are pilot sub-carriers that the system uses as a reference to disregard frequency or phase shifts of the signal during transmission.

A pseudo binary sequence is sent through the pilot sub-channels to prevent the generation of spectral lines. The remaining 48 sub-carriers provide separate wireless pathways for sending the information in a parallel f ashion. The resulting sub-carrier frequency spacing is 0.3125 MHz (for a 20 MHz with 64 possible sub-carrier frequency slots).

The primary purpose of the OFDM PHY is to transmit Media Access Control (MAC) protocol data units (MPDUs) as directed by the IEEE 802.11 MAC layer. The OFDM PHY is divided into two elements: the physical layer convergence protocol (PLCP) and the physical medium dependent (PMD) sub-layers.

The MAC layer communicates with the PLCP via specific primitives through a PHY service access point. When the MAC layer instructs, the PLCP prepares MPDUs for transmission. The PLCP also delivers incoming frames from the wireless medium to the MAC layer. The PLCP sublayer minimizes the dependence of the MAC layer on the PMD sublayer by mapping MPDUs into a frame format suitable for transmission by the PMD.

Under the direction of the PLCP, the PMD provides actual transmission and reception of PHY entities between two stations through the wireless medium. To provide this service, the PMD interfaces directly with the air medium and provides modulation and demodulation of the frame transmissions. The PLCP and PMD communicate using service primitives to govern the transmission and reception functions.

Figure (E-I) illustrates the frame format for an IEEE 802.11a frame. The PLCP preamble field is present for the receiver to acquire an incoming OFDM signal and synchronize the demodulator. The preamble consists of 12 symbols. Ten of the symbols are short for establishing Automatic Gain Control (AGC) and the coarse frequency estimate of the carrier signal. The receiver uses the long symbols for fine-tuning. With this preamble, it takes 16 microseconds to train the receiver after first receiving the frame.

PLLP preamble (12 symbols)	Rate (4 bits)	Reserved (1 bit)	Length (12 bits)	Parity (1 bit)	Tail (6 bits)	Service (16 bits)	PSDU (payload)	Tail (6 bit)	Pad

Figure (E-I). Frame formats

(Source –Vocal Technologies Ltd.)

The signal field consists of 24 bits, defining data rate and frame length. The IEEE 802.11a version of OFDM uses a combination of binary phase shift keying (BPSK), quadrature PSK (QPSK), and quadrature amplitude modulation (QAM), depending on the chosen data rate as it is shown in Table (E-I). The length field identifies the number of octets in the frame. The PLCP preamble and signal field are convolutionally encoded and sent at 6 Mbps using BPSK no matter what data rate the signal field indicates, The convolutional encoding rate depends on the chosen data rate.

Data Rate (Mbps)	Modulation	Coding Rate	Coded bits per sub-carrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	16-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Table (E-I) – IEEE 802.11a Modulation Techniques

(Source –Vocal Technologies Ltd.)

The service field consists of 16 bits, with the first six bits as zeros to synchronize the de-scrambler in the receiver, and the remaining nine bits are reserved for future use (and set to zeros). The PLCP service data unit (PSDU) is the payload from the MAC layer being sent. The pad field contains at least six bits, but it is actually the number of bits that make the data field a multiple of the number of coded bits in an OFDM symbol (48, 96, 192, or 288). A data scrambler using a 127 bits sequence generator scrambles all bits in the data field to randomize the bit patterns in order to avoid long streams of 1s and 0s.

With IEEE 802.11a OFDM modulation, the binary serial signal is divided into groups (symbols) of one, two, four, or six bits, depending on the data rate chosen, and converted into complex numbers representing applicable constellation points. If a data rate of 24 Mbps is chosen, for example, then the PLCP maps the data bits to a 16QAM constellation.

After mapping, the PLCP normalizes the complex numbers to achieve the same average power for all mappings. The PLCP assigns each symbol, having a duration of 4 microseconds, to a particular sub-carrier. An Inverse Fast Fourier transform (IFFT) combines the sub-carriers before transmission.

As with other IEEE 802.11 based PHYs, the PLCP implements a clear channel assessment protocol by reporting a medium busy or clear to the MAC layer via a primitive through the service access point. The MAC layer uses this information to determine whether to issue instructions to actually transmit an MDSU.

Operating frequencies for the IEEE 802.11a OFDM layer fall into the following three 100 MHz unlicensed national information structure (U-NII) bands: 5.15 to 5.25 GHz, 5.25 to 5.35 GHz, and 5.725 to 5.825 GHz. Table (E-II) shows that there are twelve 20 MHz channels, and each band has different output power limits. In the United States, the Code of Federal Regulations, Title 47, Section 15.407, regulates these frequencies.

The IEEE 802.11a standard requires receivers to have a minimum sensitivity ranging from -82 to -65 dBm, depending on the chosen data rate.

Band	**Channel numbers**	**Frequency (MHz)**	**Maximum output power (up to 6 dBi antenna gain)**
U-NII lower band 5.15 to 5.25 GHz	36	5180	40mW (2.5mW/MHz)
	40	5200	
	44	5220	
	48	5240	
U-NII Mid band 5.25-5.35 GHz	52	5260	200mW (12.5mW/MHz)
	56	5280	
	60	5300	
	64	5320	
U-NII Upper band 5.725-5.825 GHz	149	5745	800mW (50mW/MHz)
	153	5765	
	157	5785	
	161	5805	

Table (E-II) - OFDM Operating Bands and Channels.

(Source –Vocal Technologies Ltd.)

IEEE ratified the IEEE 802.11a and IEEE 802.11b wireless networking communications standards in 1999, to create a standard technology that could span multiple physical encoding types, frequencies and applications in the same way the 802.3 Ethernet standard has been successfully applied to 10, 100 and 1,000 Mbps technology over fiber and various kinds of copper.

IEEE 802.11b standard was designed to operate in the 2.4 GHz band using Direct Sequence Spread Spectrum (DSSS) technology. The IEEE 802.11a standard, on the other hand, was designed to operate in the 5 GHz UNII (Unlicensed National Information Infrastructure) band. the IEEE 802.11a standard uses Orthogonal Frequency Division Multiplexing scheme.

The IEEE 802.11a standard, which supports data rates of up to 54 Mbps, is the Fast Ethernet analog to IEEE 802.11b, which supports data rates of up to 11 Mbps. Like Ethernet and Fast Ethernet, IEEE 802.11b and IEEE 802.11a use an identical MAC (Media Access Control). However, while Fast Ethernet uses the same physical-layer encoding scheme as Ethernet (only faster), IEEE 802.11a uses an entirely different encoding scheme, called OFDM (Orthogonal Frequency Division Multiplexing).

The FCC has allocated 300 MHz of spectrum for unlicensed operation in the 5 GHz block, 200 MHz of which is at 5.15 MHz to 5.35 MHz, with the other 100 MHz at 5.725 MHz to 5.825 MHz. The spectrum is split into three working "domains." The first 100 MHz in the lower section is restricted to a maximum power output of 50 mW (milliwatts). The second 100 MHz has a more generous 250-mW power budget, while the top 100 MHz is delegated for outdoor applications, with a maximum of 1-watt power output. In contrast, IEEE 802.11b cards can radiate as much as 1 watt in the United States. However, most modern cards radiate only a fraction (30 mW) of the maximum available power for reasons of battery conservation and heat dissipation.

The IEEE 802.11a standard gains some of its performance from the higher frequencies at which it operates. Moving up to the 5 GHz spectrum from 2.4 GHz will lead to shorter distances. The IEEE 802.11a technology overcomes some of the distance loss by increasing the EIRP to the maximum 50 mW.

OFDM was developed specifically for indoor wireless use and offers performance much superior to that of spread-spectrum solutions. OFDM works by breaking one high speed data carrier into several lower speed sub-carriers, which are then transmitted in parallel in a DMT way, as used by the ADSL modems. Each high speed carrier is 20 MHz wide and is broken up into 52 sub-channels, each approximately 300 KHz wide. OFDM uses 48 of these sub-channels for data.

Each sub-channel in the OFDM implementation is about 300 KHz wide. At the low end of the speed gradient, BPSK (binary phase shift keying) is used to encode 125 Kbps of data per channel, resulting in a 6,000 kbps, or 6 Mbps, data rate. Using quadrature phase shift keying, you can double the amount of data encoded to 250 Kbps per channel, yielding a 12 Mbps data rate. And by using 16 level quadrature amplitude modulation (4QAM) encoding 4 bits per hertz, you can achieve a data rate of 24 Mbps. The IEEE

02.11a standard specifies that all IEEE 802.11a compliant products must support these basic data rates.

APPENDIX F

Questionnaire to the Stakeholders .

- In terms of new innovative services, what category of applications, should be considered as licence exempted in 2.4 GHz and 5GHz frequency bands?

- Should the public telecommunication services (Data and Internet related services) operate in this band be opened up for new entrants, and of so, on what basis should it be considered?

- What type of public and private telecommunication services be offered in these bands and what is the anticipated market potential.?

- Are there any potential problems associated with allowing commercial/public services in these bands?

- What practical measures be used to reduce the likelihood of interference? What practical problems can be foreseen if all category of applications are licence exempted ?.

- Is there any requirement for licensing of high power applications, if so on what basis?.

- What practical measures be taken to clear the present non data related services in the 2.4 GHz band?.

Annexure I
Bluetooth Products

I. Office Equipment

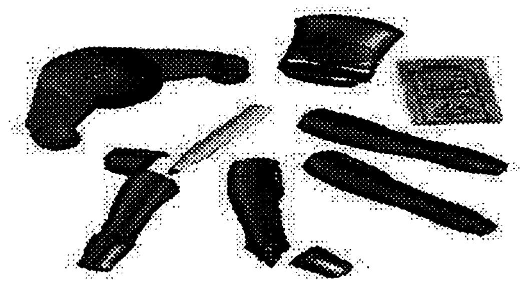


Figure (I-a) eBeam Wireless Interactive Whiteboard System
(Source – Official Bluetooth Website)

The eBeam Wireless Interactive Whiteboard System with *Bluetooth*® wireless technology is an interactive whiteboard appliance, that allows to digitally capture meeting notes and diagrams as they are created. The eBeam Wireless System is compatible to PC, Mac, PocketPC and Palm OS. traditional interactive whiteboards and copyboards, the eBeam systems are mobile, easy to install, and web-enabled. Consisting of a small receiver, pen sleeves, standard dry-erase markers, and an eraser - eBeam systems can be carried in a laptop case and are installed in minutes.

II. Audio Players

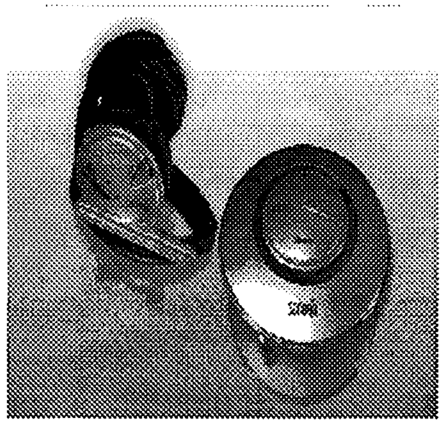


Figure (I-b) Bluetooth Audio Player OBH-0100
(Source – Official Bluetooth Website)

The SONORIX Bluetooth Audio Player OBH-0100 is the first product of its kind in the world to integrate Mobile, Wireless and Audio technologies into a multi-purpose entertainment device, thereby providing the user with the Ultimate Solution for hands-free and audio demands. The key profiles supported in addition to the basic profiles are A2DP, Headset profile and Hands-free profile.

III. Keyboards

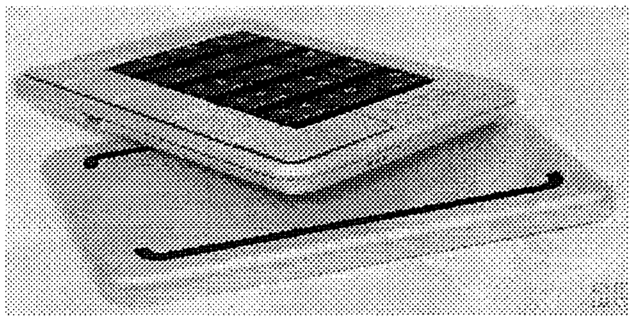


Figure (I-c) Bluetooth FrogPad Portable Keyboard
(Source – Official Bluetooth Website)

An elegantly small, intuitive and powerful interface for input and information access with a variety of devices. It solves the keyboard limitations that until now have stood in the way of achieving the objective of information access anytime, anywhere and from any device.

IV. Home Appliances

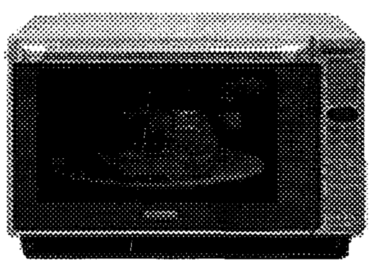


Figure (I-d) TOSHIBA Combination Microwave Oven
(Source – Official Bluetooth Website)

Using the Bluetooth, microwave oven can receive the heating pattern code from the home terminal on radio, and heating control can be automatically carried out based on this code.

V. Printers

Figure (II-e) A-631 Bluetooth, Wireless Printer
(Source – Official Bluetooth Website)

The A631 portable thermal printer is the first product that AXIOHM has chosen to implement the Bluetooth V1.1 wireless technology. The battery operated A631 communicates with any equipment including a BluetoothTM emitter by RF up to 10m of distance and with a 1 Mb/s data transmission flow while maintaining this printers' performance.

Annexure II

Case Studies on Wireless Broadband Applications

I. Community Broadband Networks

_i._ EastServe Metropolitan Area Wireless Network
Unlicensed Spectrum for Underserved Urban Areas

While policy makers in the U.S. debate over how to bridge the last mile, unlicensed technology is giving disadvantage communities the ability to confront and solve access issues for themselves. One shining example is the case of the EastServe network in East Manchester, England, where community members have installed a wireless broadband network connecting 350 households, 17 area schools, and nine community technology centers.

The EastServe network was created by residents from the towns of Beswick, Clayton and Openshaw through the British government's "Wired Up Communities" initiative, which pulls public and private entities to bring broadband Internet to disadvantaged areas. There are seven pilot communities across England in the Wired Up Communities initiative, each of which is using a slightly different technology to learn the best strategy to reach the UK last mile.

For East Manchester, wireless was the only viable solution. Ninety percent of the population have no high-speed cable access, and 25% have no fixed-line phone service since many households only use mobile phones. With 80% of the population living in houses, almost half of which are publicly funded, the expense of laying cable or a DSL loop to each residence is especially prohibitive. But a wireless solution, with its flexible and facile installation, allows community stakeholders to set-up, manage and trouble-shoot technical problems themselves.

A local company, Gaia Technologies, has trained resident volunteers to install and maintain the 10 community access points currently in place. Volunteers from the neighborhoods will add an additional 15 access points in the next phases of the project.

Over 700 households within a 6-mile area have signed up for the service, and project leaders estimate that with the ease of rooftop installation they can bring 100 new users per week onto the network.

Gaia Technologies Managing Director, Anas Mawla says the network is a ring formation of six backbone towers, which are located among the 17 schools and nine on-line centers on the network. These six towers provide a total of 45 Mbps of data transmitted in narrow beam, point-to-point connections on the 5.8 GHz band. The backbone relies on a partial mesh design for redundancy. Proxim makes the 5.8 GHz transceivers.
Within this ring of towers, twenty-five 802.11b access points transmit in wedge-shaped sectors to reach households with up to 11 Mbps of data to be shared among users. EastServe uses Cisco Systems' Aironet customer premise antennas for the last-mile link to houses. Flat dwellers share a wireless link that connects directly to the backbone.

Since activating the network, the local telephone carrier has launched limited ADSL access to parts of East Manchester, however this service offers a much slower, asymmetrical service at higher prices than the EastServe wireless network. EastServe users also have access to a community Intranet; customer service provided by community members; and the ability to purchase new or recycled computers through the program. They also have the added comfort that they will soon own and maintain their network, no longer at the mercy of a third-party provider to bring them the service.

ii. Making the Last Mile First in Developing Economies

Unlicensed Networks Reaching the Poorest of the Poor

A general rule in introducing new technologies to developing economies is that one size does not fit all. Often, for a new technology to be economically viable in developing countries, substantial changes in the model must be made. Now that unlicensed wireless technologies are bridging the last-mile service gap for hundred's of thousands of homes in America, efforts have begun to make the wireless model work in developing economies.

The Dandin Group, an unlicensed wireless engineering firm, has built successful networks on the island of Tonga and in the capital of Mongolia, Ulaan Bataar. China

Unicom has begun unlicensed fixed wireless deployments in the Guangzhou and Shenyang provinces, and China Netcom has built over 2,000 Wi-Fi hotspots in four of China's largest cities. But most deployments only reach relatively high-income users.

The biggest barrier to reaching the poorest of the poor is the high cost of equipment compared to the scant resources of individual users. Wireless Internet service providers need new ways to aggregate users and get the most out of each piece of technology. FirstMile Solutions, a consultancy of MIT Media Lab engineers, has taken a novel approach to this problem, effectually turning the mobility model on its head. Instead of building stationary transmitter towers to reach mobile users, as cellular phones work, FirstMile engineers in India have been experimenting with Mobile Access Points (MAPs) to bring high-speed connectivity to rural villages. By mounting wireless access points onto buses with daily routes to rural villages, one access point is able to serve many villages with periodic service.

The bus-mounted MAPs connect to Wi-Fi enabled computer centers located near the bus routes. Users are able to write email messages or record digital video messages, as in a typical Internet café. Then, when the bus drives by, the access point connects with the computer center and uploads all the stored files from the previous 24-hours, and delivers new messages to user in-boxes. When the bus drives back to its point of origin in a larger town, it connects with a fixed-base Internet connection and uploads all the data collected in its rounds, and downloads new data to be delivered the next day on its route.

The project is designed to fit the needs of rural villages lacking the resources or the demand for full-time connectivity. The periodic, "store-and-forward" connection provides an email application previously unavailable to rural villagers, which can be purchased as needed from a local Internet café.

II. Municipal Broadband Networks

The municipal attraction to unlicensed wireless networking lays in the amount of taxpayer money local governments can save by building these networks rather than laying expensive fiber rings or even more costly last-mile wired service to residents and businesses. Also, for municipalities that own their own water towers, streetlights, and other infrastructure, the wireless solution is an ideal way to leverage local assets and provide additional services to citizens while generating reoccurring revenue without great investment. But perhaps the greatest incentive to municipalities is not one of choice, but rather of necessity. Most of the governments who have built these networks are smaller, more rural towns and populations that have long-been ignored by the large telecoms.

i. The Rockwood Area School District Unlicensed Educational Network

A Wireless Model to Connect Rural School Communities

While U.S. school districts have been issued the command to "leave no child behind," many rural schools are without the resources to bring broadband Internet access into their classrooms. This is especially true for rural communities beyond the reach of DSL or cable lines. This last-mile problem presents hardships not only for schools, but also for local households and businesses unable to fully participate in the information economy. A public/private partnership has been formed in western Pennsylvania to use unlicensed spectrum and the social capital of local school districts to address the last mile on their own. Thus far, the efforts of the Broadband Rural Access Information Network (BRAIN) have yielded great results connecting rural areas, and their example could provide a template for other rural school communities across the country.

The BRAIN effort began with the vision of a small school district superintendent, Andy Demidont, and the help of a large regional WISP, Sting Communications. Demidont wanted to provide high-speed access to the Rockwood High School and the Kingwood Elementary School in mountainous Somerset County. The schools' existing dial-up accounts were expensive, and rendered connection speeds barely surpassing 14 kbps.

Relying on the technical guidance from Sting Communications, and using grant money awarded from the Individuals with Disabilities Act and E-Rate discounts, the school district installed wireless access points on the roofs of both schools, turning each school into state-of-the-art wireless hotspots.

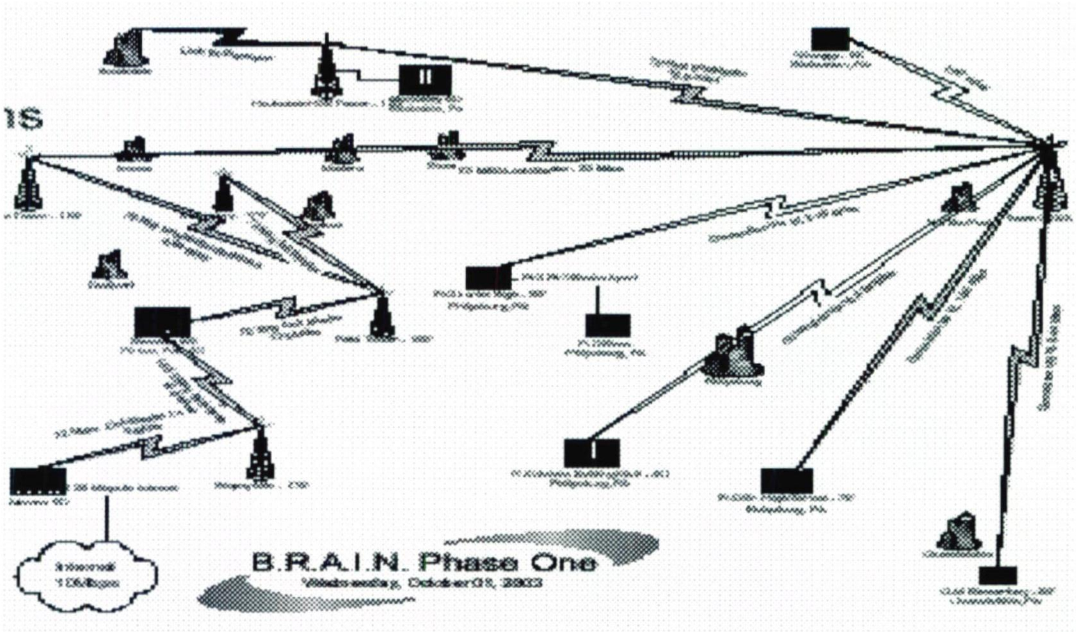
In total, Sting Communications installed three towers, creating a pie-shaped hot-zone using the 5.8 GHz and 2.4 GHz license-exempt bands. The Rockwood High School gymnasium hosts a 100-foot tower that transmits to a 150-foot tower located at

Kingwood Elementary school. The two towers share a narrow beam, point-to-point connection with a third tower owned by the local Seven Springs Ski Resort.

Simply bringing the technology to the area wasn't the end goal – using the network to connect the school with the community is the ultimate design of the project. Both the Rockwood and Kingwood schools have put many classroom and administrative operations on-line. Teachers use Palm Pilots and laptops to track student progress, design lessons, and record grades – which are available to parents online. Students can use the high-speed connection in each classroom, with each school "unwired" for access.

The project was designed to also give community residents a chance to purchase access from the school's network, with the school district serving as a WISP for the area. Between the three towers, Sting has installed access points in neighborhoods to provide coverage for much of the community. Sting has also provided an incentive for community members to join the network, by offering subscription rates between $11 and $20 per month, depending on the number of subscribers the school can attract. Thus far, 65 families have joined the network.

From the project's onset, Sting hoped their approach could be replicated in other rural school communities. Building on what they have learned in Somerset County, Sting has built a much larger network in Cambria and Clearfield Counties to connect four more regional school districts. Sting Vice President Bob Roland says that this new network spans an 1100 square mile area, reaching residents of the Glendale, Philipsburgh, Osceola, and Moshannon Valley school districts. This network uses both 5 GHz frequency-hopping spread spectrum and 802.11 connections for the last mile.



Sting Communications

- Provide wireless services to about 100 towns in Pennsylvania
- Provides sub-T 1 to 480Mbps connections
- Top 5 USA WISP
- Over Alvarion-based 1,000 subscribers
- Experts at leveraging grants, e-Rate funding
- Expanding into neighboring states
- Deploying BreezeACCESS Complete Spectrum™ (900 MHz, 2.4GHz, 5GHz)

III. Commercial Wireless Broadband Networks

i. Think Globally, Act Locally – AMA*TechTel & Prairie iNet

WISPs Evolve from Hot Spots, to Hot Zones, to Regional Broadband Providers

At the onset of the unlicensed movement, Wireless Internet Service Providers (WISPs) were typically small-scale efforts to bring broadband access to local areas using adapted WiFi equipment. Many of these efforts were scaled-up versions of the WiFi hotspots, now ubiquitous in urban coffee shops, hotel lobbies, and even some public parks. In recent years, however, unlicensed equipment has advanced well beyond WiFi to include more sophisticated technologies -- such as frequency-hopping, non-line-of-sight transmitters, mesh networks, and high-gain directional antennas that can make point-to-point connections over 20 miles. These days, providers construct networks into scalable cell sectors with varying levels of redundancy and security based on customer need, and they carefully engineer their deployments to accept more subscribers without compromising service as the network expands. In fact, the most successful WISPs have long-since outgrown the hotspot model and are now building contiguous wide-area networks that have raised the standard for unlicensed service.

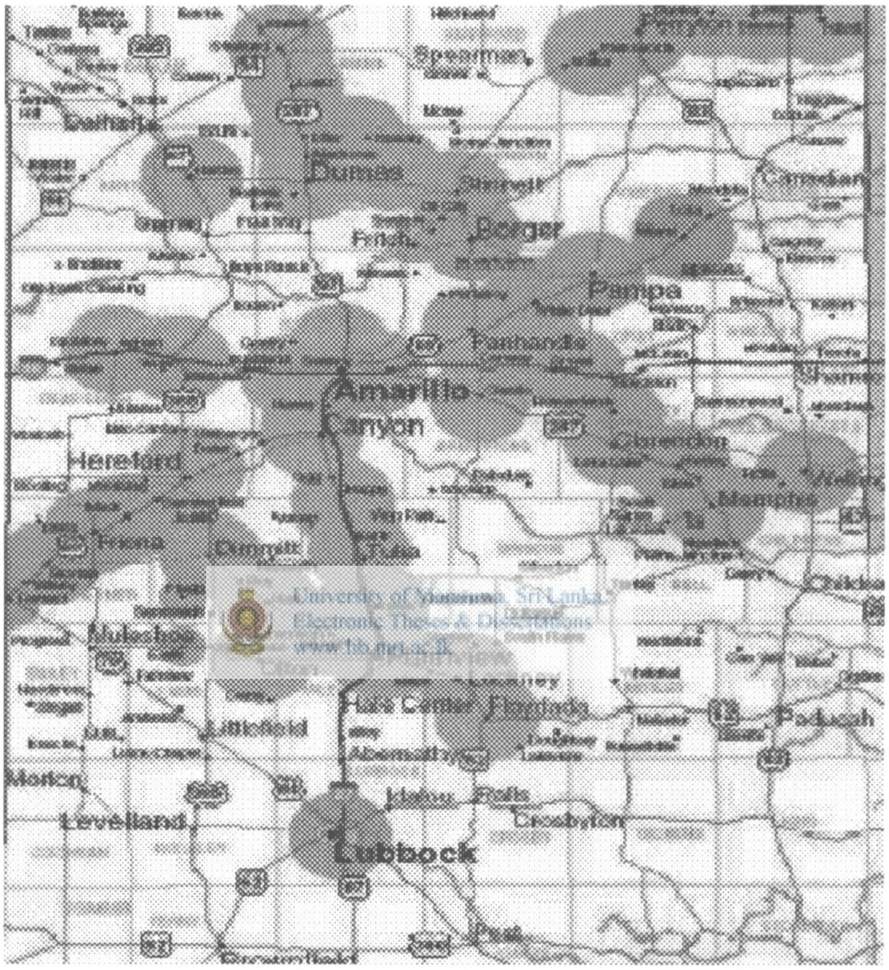
One company that is redefining the notion of a WISP is AMA*TechTel Communications of Amarillo, Texas. With more than 4,000 users on their license-exempt network, AMA*TechTel is one of the country's largest regional carriers of wireless broadband. The company has built a 20,000 square mile, organic network comprised of 63 transmitting towers stretching across the North Texas plains.

According to Patrick Leary, Assistant Vice President of Marketing for Alvarion, one of the largest manufacturers of broadband wireless technology, the AMA deployment is a sophisticated, contiguous network that provides secure service to residential, corporate and educational campuses. Using Alvarion transmitters and multiple unlicensed bands (to include 900 MHz, 2.4 GHz, and 5 GHz) AMA has created private virtual environments for three college campuses, multiple school systems, law enforcement and public safety agencies, hospitals, and numerous banks within their expanding footprint.

The company is now building a wireless backbone for Texas Tech University that will connect Amarillo to Hobbs, New Mexico and provide broadband access to communities along its route. This wide area network will support K-12 and adult education and business development programs.

The expansiveness of the AMA network is due to the company's partnership with Attebury Grain, a large grain storage company that contracted AMA to connect their grain elevators to the commodities market. After the project, the two companies combined forces to widen the network using Attebury's numerous grain elevators to reach towns and businesses within line-of-sight of the elevator towers.

The wireless service is becomingly increasingly popular with residents in North Texas towns who may or may not have DSL access. According to AMA*TechTel Vice President of Business Development, Douglas Campbell, the company has been growing by 150 new subscribers a month with very little marketing.



AMA TECHTEL

AMA Techtel

- Privately held CLEC in Amarillo, TX
- Offers Internet and VPN services
- Achieved rapid return on investment
- Covering 20,000 square miles
- Almost 6,000 CPE installed
- Deploying BreezeACCESS Complete Spectrum™ (900MHz, 2.4GHz,5GHz)

ii. Revolution in the Rural Last Mile – Roadstar Internet Services
Unlicensed Spectrum Closing the Technology Divide in Northern Virginia

Despite their proximity to northern Virginia's Internet backbone, many towns in Loudoun County have no broadband access. The mountainous western regions of the county are far from the technology infrastructure of Northern Virginia where companies like AOL and VeriSign reside. However, because of license-exempt wireless activity, the technology divide across the county is starting to close.

The Northern Virginia area profited from the technology boom of the late 90s. But, when the technology bubble burst, as many as 30,000 jobs in the region were lost. Many laid-off professionals accustomed to broadband connections at their work started their own businesses or began working from their homes, creating a large demand for high-speed home services. One local company, Roadstar Internet, is meeting that demand by building a rapidly growing wireless network in rural Loudoun County.

Started in the autumn of 2002, the Roadstar Internet network connects more than 150 rural households and small businesses using 100% unlicensed spectrum. Most wireless subscribers do not know exactly how their service operates; since what matters most to users is that their connections are fast and reliable, and not necessarily the technology behind the service. But, the Roadstar unlicensed network is similar in design to many other WISP efforts, and uses a combination of point-to-point connections for the long-distance transmissions, and point-to-multipoint transmissions to connect neighborhood access points to subscribers.

The first leg of the network travels 18 miles from a mountaintop transceiver using 5 GHz license-exempt bands. Roadstar uses OFDM (Orthogonal Frequency Division Multiplexing) technology that allows for point-to-point connections without perfect line-of- sight. OFDM transmissions make efficient, and secure, use of spread spectrum by dividing data into packets and encoding it over multiple frequencies.

Long distance point-to-point transmissions are the standard for rural WISPs seeking to extend their markets and reach larger population pockets. Under Part 15 rules for unlicensed usage, the FCC allows operators to make point-to-point connections without reducing Transmitter Power Output (TPO) for the 5.725 GHz and 5.825 GHz band. Because of this regulatory latitude for narrow beam transmissions, providers are able to reach long line-of-site distances with relatively low power.

The Roadstar network makes final, last-mile connections within neighborhoods by using modified WiFi wireless access points mounted on customer silos, barns and rooftops. Roadstar and other WISPs are able to transmit distances greater than the 300-foot standards for WiFi, 802.11b technology by creating sectorized cells with high-gain, directional antennas. These last-mile connections on the 2.4 GHz band are the result of good planning and engineering, and typically reach two to three miles.

References

802.11 Wireless LAN Performance, White paper, Atheros Communications, 2003
http://www.atheros.com/pt/papers.html (viewed on July 2004)

Alvarian
http://www.alvarion.com/ (viewed on August 2004)

Australian Communications Authority, "Class Licensing",
http://www.aca.gov.au/aca_home/publications/reports/info/spreadsp.htm ,
(viewed on August 2004)

Australian Communications Authority, "Planning Development, Radio LANs"
http://www.aca.gov.au/frequency/WLAN.htm (viewed on August 2004)

Barranca M. "Unlicenced Wireless Broadband Profiles", Spectrum Policy Programme, April 2004.

Bhatiya B., "Motorola Comments on the Consultation paper published by TRCSL", Motorola Innovation Center, 2003

Bluetooth, The Official Bluetooth Website
http://www.bluetooth.com (viewed on August 2004)

Davis C., "Options for the greater use of wi-fi and other unregulated applications", Quotient Associates Ltd, UK & The Ministry of Economics Reforms Science and Technology, Sri Lanka, March 2003

De Vries P and Hassan A., "Spectrum Sharing Rules for New Unlicenced Bands", Microsoft Corporation, December 2003

Federal Communications Commission, USA, "2002 CFR Title 47, Part 15",
http://www.access.gpo.gov?nara/cfr/waisddx_02/47cfrl5_02.html , (viewed on July 2004)

Final Acts, International Telecommunications Union, 2003

Guideline on the provision of wireless LAN service using spread spectrum communication equipment", Malaysian Communications and Multimedia Commission.
http://www.mcmc.gov.my (viewed on August 2004)

"IEEE 802.11a Wireless LAN", VOCAL Technologies Ltd.
http://www.vocal.com/data-sheets/ieee-802.11a.html (viewed on July 2004)

Info-Communications Development authority, Singapore, "Type Approval Specifications for Spread Spectrum Systems(wireless LAN and Bluetooth Devices)'
http://www.ida.gov.sg (viewed on September 2004)

Judge, Peter, "Wi-Fi to overtake broadband", TECHWORLD, 2003

Leary P., "Rural U.S. Examples of Wireless Broadband Deployments", Alvarian , Inc, May 2004

Lehr W., "Economic Case for Dedicated Unlicenced Spectrum Below 3 GHz", Massachusetts Institute of technology, 2004

Kru 's J, "Co-existance of Dissimilar Wireless Systems", Cisco Systems, December 2003

"Making 2.4 GHz, 5GHz bands available for licence exempt terminal", Consultation Document. Telecommunications Regulatory Commission of Sri Lanka, June 2003

Office of Communications UK, "Licencing arrangements for 5 Ghz RLAN Equipment in similar FWA Services", www.ofcom.org.uk/licensing-numbering , (viewed on September 2004)

Office of Communications UK, "Deregulated FWA,Mobile Data and RLAN Licensing ", www.ofcom.org.uk/licensing-numbering , (viewed on August 2004)

Office of the Telecommunications Authprity,hong Kong,"Class Licence for provision of Public Wireless Local Area Network services", http://www.ofta.gov.hk/legislation/class-licence/wlan_lic.pdf , (viewed on August 2004)

Peha J.M. "More Market Mechanisms in Moderation (M4)", Centre for Wireless and Broadband Networks, July 2002

"Providing Telecommunications Services over frequencies not specifically assigned to their user in the 2.4GHz & 5GHz bands (WLAN)",Consultation Document. Autorite' de de re'gulation des telecommunications, France., December 2001. http://www.art-telcom.fr/publications/rlan/rlanresponseng.htm (viewed on July 2004)

Radio Communications Agency, UK, "Short range , High Data Rate, Nomadi Equipment operating in the frequency range 5.150-5.875 Ghz" http://www.radio.gov.uk/topics/mobiledata/consult/5ghz/5ghz.htm, (viewed on August 2004)

Radio Communications Agency, UK,"use of Licence –Exempt Spectrum for wireless Local Area Networks" http://www.radio.gov.uk/topics/mobiledata/rlans-licence-exempt/q-a.htm, (viewed on August 2004)

Radio Regulations, International Telecommunications Union, 2003

Shim, Richard, Wi-Fi gear moving double, CNET News, 2004

The 802.11 Report
http://www.80211report.com/topics/802.11.html (viewed on July 2004)
http://www.80211report.com/topics/hotspots.html (viewed on July 2004)
http://www.80211report.com/topics/wifi_wlan.html (viewed on July 2004)

"Use of Licence-Exempt Spectrum for provision of Public Telecommunication Services" Consultation Document, Radiocommunications Agency, United Kingdom, October 2001
http://www.radio.gov.uk or http://www.ofcom.org.uk (viewed on July 2004)

Wi-Fi Alliance
http://www.wi-fi.org/opensection (viewed on August 2004)

"Worldwide Regulatory Progress for Wireless LANS", Atheros Communication, 2003
http://www.atheros.com/pt/papers.html (viewed on July 2004)