



## PAPER ON THE POTENTIAL CARBON SAVINGS OFFERED BY THE AIRBORNE STRUCTURED MESH INFRASTRUCTURE, JULY 2008

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### ABSTRACT

Climate change is a growing cause of concern for all. Individuals, organisations and governments are doing their best to control the factors contributing to climate change and reduce its disruptive effects. Information technology, telecom/data networking can play an equally important role along the side of other direct means for solving the problem. New technology can be used to reduce the emission of green house gases into atmosphere. One such technology from Airborne Networks is a low power, structured mesh wireless communications system. The system provides a means to deploy high speed data networks. These networks use lower power radio communications and hence require lower power to operate. The networks can be deployed and operated in a more energy efficient manner. This reduces the energy requirements of the network and consequently the carbon units produced in network operation.

### RÉSUMÉ

Stephen J Webber is the inventor of the patented <sup>(1)</sup> self powered structured mesh networks. As the Founder of Airborne Networks, Stephen has over 13 years experience in the IT & Wireless Communications industry, as well as a BSc Honors Degree from the University of Reading. Daniel P Vaughan is a Senior Technical Development Engineer at Airborne Networks with over 10 years of experience as a practitioner in the IT & Wireless communications sector.

## 1 INTRODUCTION

Over the past few years there has been significant drive towards energy efficiency and carbon neutrality. There is a significant role for IT and wireless communications to play in this process. The design of Airborne's structured mesh and structured meshing microBTS mesh nodes (mBTS) can achieve practical network deployment and operational carbon savings. This paper further describes how low powered wireless connections are still capable of delivering good bandwidth, and how these subsequent savings are achieved and attempts to quantify the potential carbon savings using WiMax as the wireless communications standard for basis of calculations.

## 2 TECHNOLOGICAL FACTORS TO ACHIEVE A LOW POWERED WIRELESS NETWORK

In order to determine the practicality of running low power wireless networks there are three main critical factors used to calculate the link viability. These are the transmit power of the radio, the link distance and its associated signal losses, and the radio receive sensitivity. These factors are individually addressed in this section along

with a link budget example incorporating the low power properties.

### 2.1 Transmit Power

A significant property of a wireless link that can be used to reduce the network power requirements is transmitting power. This is the amount of power required by the device to send a signal to another radio device. For the sake of this example the transmit power is measured in dBm. Zero dBm equals one milliwatt. A 3 dB increase represents roughly doubling the power, which means that 3 dBm equals roughly 2 mW. For a 3 dB decrease, the power is reduced by about one half, making -3 dBm equal to about 0.5 milliwatt. To calculate a power P expressed as dBm the following equation may be used:

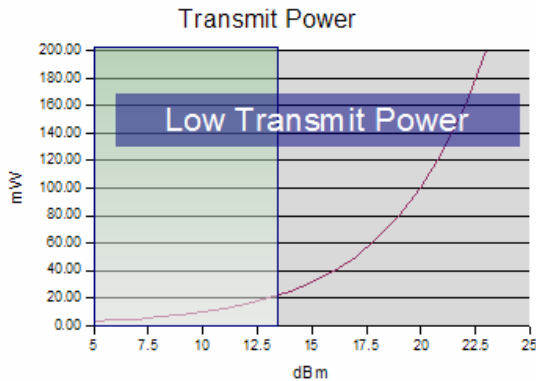
$$x = 10 \log_{10}(P)$$

For example a typical cellular phone transmission power is 27dBm which equates to 500mW (*Maximum output from a UMTS/3G mobile phone - Power class 2 mobiles*)

The graph included in this section plots mW of energy to dBm and it can be seen that 12dBm of transmit power can be generated from 20 mW of energy. The transmit

<sup>1</sup> European Patent EP172839, GB2411545

power of 12dBm will be used in the link budget equations at the end of this section.

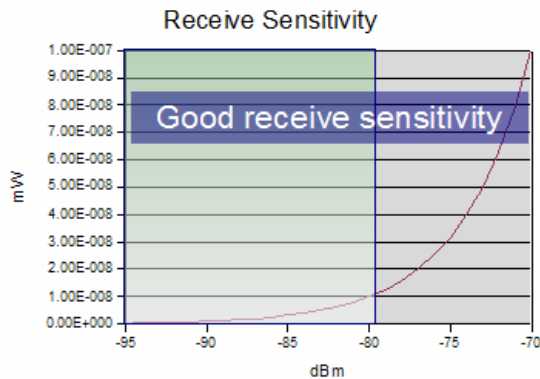


A significant benefit of reducing the radio transmit power is that this will further help to reduce the ambient noise floor in the operational environment. A reduced noise floor lowers the level of power required to be detected by the receiver radio, but still maintains a high quality connection.

## 2.2 Receive Sensitivity

Receive sensitivity is typically expressed as a negative dB integer. The lower the negative integer the more sensitive the radio is and the lower the amount of detected signal energy that is required to be received in order to decode a data stream.

Typically when operating under lower perceived signal strength conditions a WiMax compliant radio will adjust its modulation scheme (from 64QAM<sup>2</sup> to BPSK<sup>3</sup>). To encode less data onto the signal, reduces the likelihood of transmission errors, but also reduces the amount of usable bandwidth for the end user. Therefore, the power cannot drop below a certain level otherwise the connection bandwidth becomes less useful to the end user. A good receive sensitivity of -91dBm will be used in the link budget example illustrated at the end of this section.



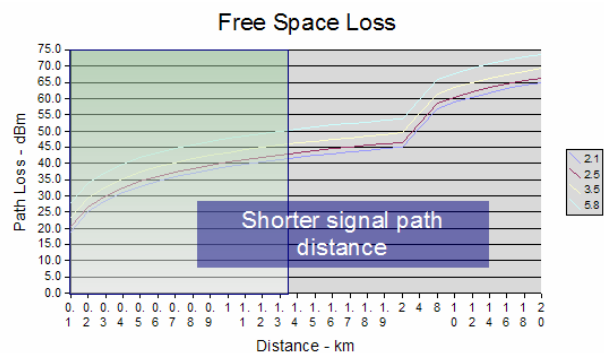
<sup>2</sup> 64 Quadrature Amplitude Modulation  
<sup>3</sup> Binary Phase Shift Keying

## 2.3 Connection Loss Over Distance

There are many mathematical models to calculate signal propagation loss, for the example shown at the end of this section free space loss will be used based on a Line of sight link for illustrating basic signal propagation over open distances.

Free space communication links have path losses that are the inverse square of the distance. The free space loss equation can be written in several equivalent ways depending on the units of measure. For the illustration used in this paper the following equation is applied:

$$FSL (dB) = 32.45 dB + 20 * \log [frequency (MHz)] + 20 * \log [distance (km)]$$



Therefore it is clear that the shorter the link distance is the lower the power requirements to maintain that link.

## 2.4 Example Link budget

To illustrate a practical example of how these energy saving measures can still deliver a very usable and quality wireless connection, the link signal loss needs to be factored in to define perceived signal strength. The frequency selected for this example was 3.5GHz which is commonly used by licensed WiMax networks.

The following properties are defined for each end of the link from Base Transmitter Station to Subscriber Unit:

### At mBTS Node

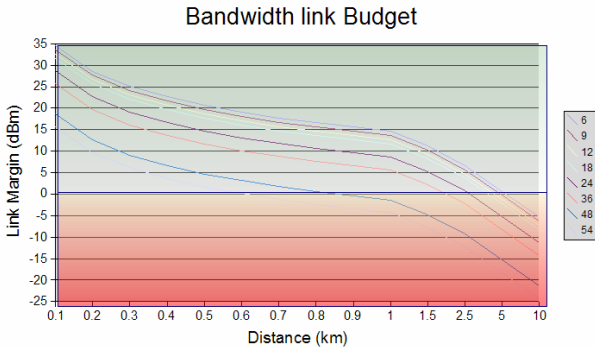
Frequency : 3,500 MHz  
 Radio Power Out : 12 dB  
 Antenna Gain : 10 dB  
 Cable & Connector insertion losses : -3.1 dB  
 Total TX System out : 18.9 dB

### At SU<sup>4</sup> node

Frequency : 3,500 MHz  
 Radio Receive In : -91 dB  
 Antenna Gain : 10 dB  
 Cable & Connector insertion losses : -3.1 dB  
 Atmospheric Margin : -5 dB  
 Total RX System in : -92.9 dB

<sup>4</sup> SU = Subscriber Unit

Using the aforementioned FSL equation the following graph plots the link margin over distance.



### 2.4.1 Link Budget Conclusions

This practical example shows that running a radio network system with a lower transmit power and incorporating good receive sensitivity radios using the 3.5 GHz frequency a 12Mb connection can be achieved up to 1km away from the mBTS.

## 3 AREAS OF POTENTIAL CARBON SAVING FOR LOWER POWER WIRELESS NETWORKS UTILISING WIMAX

There are two high level areas of energy savings in deploying a wireless network. These are Network deployment and Network Access & Operations.

### 3.1 Example Assumptions

The illustrative example we will use to show the potential carbon savings is based on a 2sq KM urban wireless network situated in the United Kingdom with 10,000 network subscribers.

### 3.2 Network Deployment

For the purpose of this paper, network deployment savings encompass the following areas, Equipment manufacturing, logistics and shipping, site preparation and build and network installation. Each of these areas of potential savings are outlined in this section

#### 3.2.1 Manufacturing

With traditional methods of deploying a WiMax network multiple pieces of equipment are needed including the WiMax BTS, Microwave links, switches, Internet Backhaul routers, housing cabinets and power supplies. The WiMax microBTS mesh nodes produced by Airborne integrate the functions of all of these components into one compact unit that can be easily fitted to existing street furniture. The true comparison calculation of the carbon units consumed in the manufacturing process is outside

the scope of this paper as Airborne is a Fabless Manufacturer and this paper will focus on the network build out and operational savings only.

#### 3.2.2 Logistics And Shipping

With traditional WiMax deployments there are multiple networking components to be shipped to site from multiple sources. For example routers, cabling, radio systems, antennas, cabinets and power supplies etc. With the microBTS nodes from Airborne the functions of these components are all integrated into one compact unit that can be shipped onsite pre-configured and ready to deploy. An example estimation comparison is shown below:

	Miles		Carbon Tons		
	Airborne	Other	Airborne	Other	Saving
Shipping Equipment to System Integrator	200	3000	0.24	3.6	3.36
to Site	200	200	0.24	0.24	0
<b>Total</b>	<b>400</b>	<b>3200</b>	<b>0.48</b>	<b>3.84</b>	<b>3.36</b>

#### 3.2.3 Site Preparation And Build

Site preparation and build encompasses the activities required to make the deployment location ready for a base station to be deployed. Traditional WiMax deployments include such items as: site concrete platform, small equipment building, security enclosure, steel radio mast, power connection and associated truck rolls for contractors and project management. Airborne microBTS reuses existing street furniture. For example street / traffic lights and other powered street furniture. It can also be deployed in a self powering mode utilising a wind & solar power source. An example estimation comparison is shown below:

	Units		Carbon Tons		
	ABN	Other	ABN	Other	Saving
<b>Site Preparation &amp; Build</b>					
Concrete for Pad (Tons)	0	43.5	0	43.5	43.5
Concrete delivery (Miles)	0	100	0	0.12	0.12
Site Construction (miles)	0	200	0	0.24	0.24
Perimeter security Fence	0	200	0	0.24	0.24
Electric Installation (miles)	100	200	0.12	0.24	0.12
<b>Total</b>			<b>0.12</b>	<b>44.34</b>	<b>44.22</b>

\* ABN = Airborne Networks

#### Assumptions:

Manufacturing one ton of concrete produces one ton of carbon<sup>5</sup>  
 Assume 20 cubic meters of concrete which equals 43.5 tons of concrete for a base station mast foundation. (Concrete has density of approximately 2.4 (dry). One ton of concrete (1000kg) has a volume of 0.417 cubic meter

<sup>5</sup> <http://www.enviroliteracy.org/article.php/1257.html>

(417L)  $1/2.4 = 0.417$ , 1 cubic meter would weigh 2.4 tons (2400kg)).  
Steel and manufacture required for mast not included in the calculations.

### 3.2.4 Network Installation

Network installation encompasses all activities carried out onsite by engineers fitting and configuring the various network components to setup the BTS. Typically there will be multiple engineer visits required to setup each of different pieces of networking equipment. The microBTS's from Airborne provide all the required networking functions and are deployed pre-configured for each site location. A summary table of the common installation visits and the potential carbon savings is shown below:

	Miles		Carbon Tons		
	Airborne	Other	Airborne	Other	Saving
Network Installation					
Backhaul	0	200	0	0.24	0.24
Router	0	100	0	0.12	0.12
BTS	200	200	0.24	0.24	0
Commissioning	0	100	0	0.12	0.12
<b>Total</b>			0.24	0.72	<b>0.48</b>

### 3.3 Network Access And Operations

There are two aspects of network operations where the Airborne structure mesh can provide savings over traditional WiMax network deployments. These are in the electricity used to power the microBTS and the electricity required by the SU / CPE to access the network.

#### 3.3.1 Network Infrastructure Power Consumption

With traditional cellular WiMax deployments the BTS is required to transmit using high power onto the antenna in order to associate and maintain a connection over longer distances and in NLOS<sup>6</sup> environments. Additionally more equipment, each with its own independent power supply is located at the BTS mast. This equipment tends not to be optimised for low power consumption. The Airborne structure mesh architecture allows for a lower power output onto the antenna due to the point of network access being located physically closer to the end user. There are considerable ongoing power savings to be made at the BTS end of a wireless link, a table below summarises the main savings and consequently the amount of carbon saved per year.

BTS Operating Power	Airborne	Other
Watts per BTS day	1226	2200
Watts per network day	18390	22000
kWh per day	18.39	22
KgCO2 per day	7.91	9.46
<b>Annual CO2 savings</b>	<b>566.59</b>	<b>kgCO2</b>

<sup>6</sup> Non Line of Sight

#### 3.3.2 End User SU/ CPE Access

With traditional WiMax networks the CPE is physically located further away from the point of access and needs to use high power output onto the antennas in order to transmit over longer distances.

Increased power consumption for mobile / portable devices reduces battery power and usable time on a single charge.

With the Airborne structured mesh architecture the CPE is located physically closer to the point of access, therefore the power required to maintain the connection is reduced.

Typical WiMax SU / CPE	Standard Mode	Low Power Mode
WiMax Pout (dB)	20	12
Power (mW)	100	20
mW per Day	2,400	480
kWh per day	0.002	0.0005
Users	10,000	10,000
Users Total kWh per year	8,760	1,752
KgCO2 per day	3,767	753
<b>Annual CO2 savings</b>	<b>3,013</b>	<b>kgCO2</b>

*Assumptions for example illustration:*

Typical WiMax radio power out – 20dB or 100mw, Airborne CPE configured for low power out – 12dB or 20mw.

## 4 CONCLUSIONS

The table below is a summary of the one off carbon savings achieved in the example network deployment based on a 2 sq KM urban wireless network situated in the United Kingdom. Numbers are expressed as tons of CO2 per network.

New network setup savings	Airborne	Other	Saving
Shipping Equipment	0.48	3.84	3.36
Site Preparation & Build	0.12	44.34	44.22
Network Installation	0.24	0.72	0.48
<b>Total</b>	<b>0.84</b>	<b>48.9</b>	<b>48.06</b>

Below is a summary table of a network operational carbon savings for the example described in this paper. All figures are expenditure or savings on an annual basis.

Network Operation CO2 Tons	Airborne	Other	Savings
BTS Network (Yr)	4.2	5.7	<b>1.5</b>
CPE Devices (Yr)	303.1	1,515.5	<b>1,212.4</b>

The figures illustrated in this example show that there are substantial carbon savings to be made on both the installation and the operation of the physical infrastructure used to run and operate the wireless network. More significantly, this type of architecture delivers substantial energy savings with the subscriber units who access the network. This type of low power network would provide a similar level of service but using approximately 20% of the energy.

## 5 DISCUSSION

It is expected that additional savings can be achieved in a number of areas; however, the quantification of these savings would require additional work. The areas are outlined below:

1. The manufacturing process. The Airborne Architecture requires less physical equipment to deliver the wireless network and hence less manufacturing.
2. The carbon cost of steel used in the masts required to deploy traditional networks.

## REFERENCES

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