SYMERA: WIRELESS TECHNOLOGY FOR WIDE AREA NETWORKS

A description of the technology used by Symera Technologies in designing and installing Wide Area Wireless Networks.
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1. Introduction

Although the benefits of wireless communications have long been acknowledged, its use for broadband transmission, as an alternative to DSL for example, has often been questioned. The main concerns have focused on the particular characteristics of wireless (spectrum, reliability, non-line-of-sight operations, scaleability) and on issues related to coverage and capacity. However, the growing demand for broadband services - and for higher speeds and larger amounts of bandwidth - has exposed the limitations of the fixed network and turned attention again to the benefits that wireless can offer.

Wireless networking is now seen as the most likely means by which Next Generation Broadband will be delivered on a universal basis. The growing interest in creating Wireless Digital Cities is testament to this.

2. Acceptance of wireless

A wide area wireless broadband network, whether designed to serve the needs of a city, a concentrated number of users on a business park or those living in more remote communities has to fulfil a number of requirement. These relate to factors such as: range and coverage; speed and bandwidth; the services offered; the capacity of the network and its ability to support the necessary number of users. Although there are several technologies now available for building wide area wireless networks, not all are capable of delivering high-speed broadband over a large catchment area and supporting a large customer base.

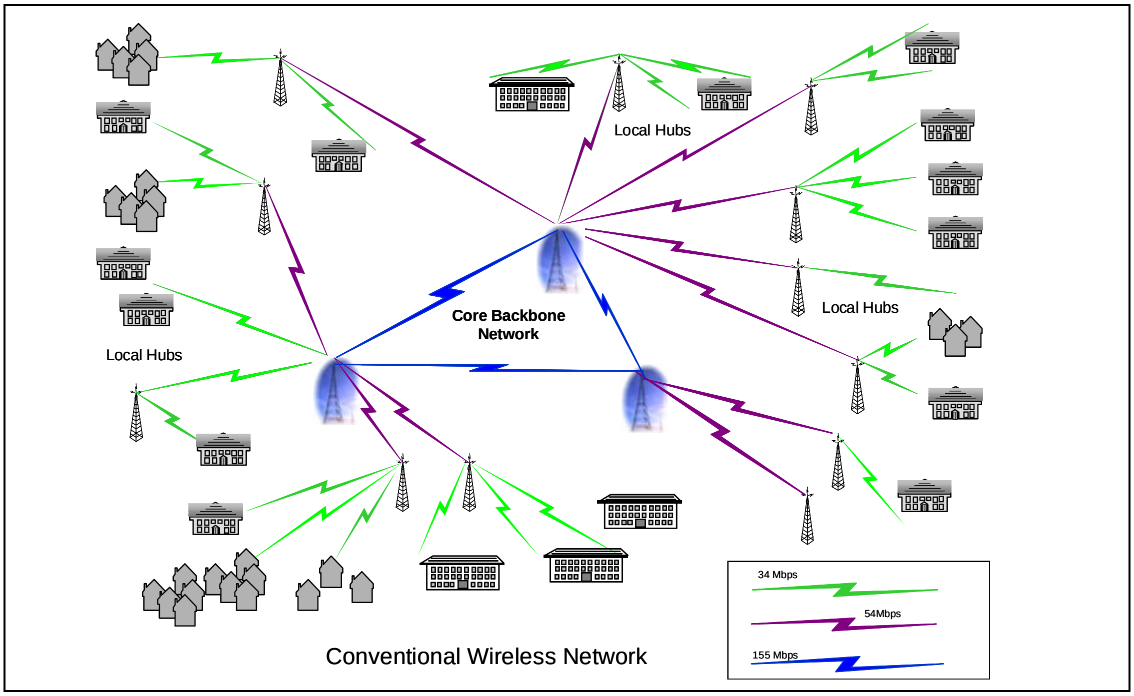
Wireless transmission has been used for a number of years by telecoms operators to carry voice and data traffic in a Point-to-Point (PTP) mode and mobile (cellular) communications has demonstrated remarkable growth since the launch of UK services in 1985. In terms of wide area networks and the use of wireless for fixed wireless access, the first decade of the 21st Century has already seen the use of wireless networks to deliver broadband services to schools, libraries, the police, hospitals etc. In fact wireless was the only way in which many of these organisations could meet the government's requirements for a "Broadband Britain".

Wireless is now coming into its own. Yet some doubts still remain as to the ability of a wireless network to support a large customer base while delivering high speeds and large amounts of bandwidth. To some extent, such doubts have been justified – at least until now.

Conventional wireless systems.

The traditional way of designing a wireless network is to use a simple linear or a star formation. However, this is a highly inefficient structure and does not take account of modern usage of systems such as any-to-any data-flows. It inevitably leads to the 'poor-neighbour effect' at the far side of the network.

With the introduction of sophisticated Layer 3 switches, at affordable prices, networks started to be designed as meshed ring-based, highly resilient structures using the routing and alternative path and load-balancing features of the new switches. The usual approach was to create a high capacity radio backbone, with strategically located nodes or hubs, from which lower capacity radio links could be connected to the end user locations.



Conventional Wireless Network

The backbone links were usually 155Mbs (fully duplex) throughput radios using, wherever possible, licensed frequency bands. The balance was determined to minimise cost, maximise throughput and ensure un-contended bandwidth to end locations. Where necessary, medium capacity radio links were used to connect to local nodes, each of which served a local community of end users – businesses, residential households, whatever. At the hubs, Layer 3 Ethernet switches were used to distribute the bandwidth from the backbone pipes to the lower capacity radios for end node connection. This network design creates a fully fault-tolerant IP-based Wireless Wide Area Network (WiWAN) and is still the most common way of designing a wide area wireless network.

In such a network, in terms of data flow, the bandwidth within the core is scaled such that the structure reflects the likely future usage of multiple any-to-any connections, minimising the impact of such usage on overall backbone capacity.

With the appropriate core network equipment, such an infrastructure can usually handle the most extreme and unpredictable peaks in traffic, while supporting data, video and voice applications and covering internet and intranet usage, VoIP, video streaming and similar applications.

However, in such a network design, much of the system architecture is required to provide the capacity and range necessary to ensure maximum coverage. The individual wireless systems lack both the data throughput and the coverage to guarantee anything near to a universal broadband service. As a result, the limited performance levels achieved by conventional wireless necessitates the use of a complex structure of modules to create a network that can deliver an acceptable level of coverage and broadband capacity at local level.

Mesh networking.

The introduction of mesh networking allowed network planners to create networks that offered greater coverage, greater capacity and greater resilience and redundancy.

Whereas conventional wireless system have been used for many years in broadcasting and for dedicated point to point communications, the introduction of mesh networking provided network architects with a useful method of building complex data networks relatively easily.

A mesh network takes advantage of the intelligence in each component part (usually the node or base station) to create a self-organising structure, where each node – and sometimes each end user – can connect to a number of other nodes. As a result, there are several routes that a signal can take from an end user to its final destination.

Meshing is thus a fundamentally different approach to network routing. It does not follow the traditional conventions of network design. In a mesh network, nodes get given their basic rules of the road and are then left to establish their connections autonomously.

The benefits can be substantial: flexibility, speed and ease of management, easy deployment, low overheads.

Mesh networking is seen as being particularly suited to wireless networks, the argument being that wireless networks need to cater for unpredictable traffic flows and variations in reception and coverage. However, although this is certainly true of (cellular) mobile networks, where traffic patterns are unknown; it is not really true of fixed wireless networks where patterns of usage and traffic flows **can** be predicted in the same way that they can in a fixed wire network. It is the element of mobility that adds the dimension of unpredictability - and even here, traffic patterns can be predicted once the network has been in use for some time.

Mesh networking creates a widespread series of multi-hop network connections between neighbouring nodes on demand. Once connected, the nodes explore the network to determine the paths available and establish their routes through it, finding the resources they need automatically as required.

Being autonomous and discovering the best route through the network on demand, there is no central control to act as a bottleneck. The node may discover many potential routes through the network and it will select the most suitable route based upon the shortest distance to reach the other node. Other criteria, such as the quality of the connection, can influence the decision, but ultimately the router decides on the routes itself and the manager only provides the ground rules. If one route becomes unworkable then the node itself will automatically seek out another route. This removes the reliance on any single point of potential failure.

However, wide area networks using meshing are complex structures and there are questions as to the resilience of structures once they get above a certain size. Experience shows that such structures can sometimes crash or fall over.

One of the problems is that all the above systems tend to use conventional wireless equipment, RF components that have little changed over the years. As a result, the RF equipment itself starts to become a limiting factor.

Recent years have seen the introduction of smart antenna systems that use high-gain antennas[1] and take advantage of the latest beamforming and beamshaping techniques. This changes the whole picture.

[1] A high-gain antenna is an antenna with a focused, narrow radiowave beam -- also known as a directional antenna. The narrow beam width allows for more precise targeting of where you want the radio signal to go. Most commonly referred to in space missions, these antennas are now used for terrestrial applications.

3. Smart antenna technology.

The term "smart antenna" has had many definitions and originated in the early 1990s in the mobile wireless industry. In the broadband fixed wireless (BFW) arena, it has come to mean the use of adaptive antenna arrays or beamformers, the most advanced smart antenna technique developed to date.

Adaptive beamforming is a technique based on directing the maximum amount of energy to individual users within a cell. Unlike omni-directional, or even sectorised systems that paint an entire cell or sector with energy - thereby wasting much of it - beamforming targets single users or groups of users individually. This technology significantly improves the performance of a wireless network while delivering higher capacity. This means that the network can support a large number of customers; at the same time network operators can realise significant increases in signal quality, throughput and coverage.

Smart antenna technology thus exploits the benefits that can be obtained from having multiple antennas in transmit and receive mode with associated coding, modulation and signal processing to enhance performance. The customer premises equipment can also use multiple antennas (if required) and smart antenna techniques can be used both for downlink and uplink operations. This improves performance even more.

> *Beamforming is the combination of radio signals from a set of small non-directional antennas to simulate a large directional antenna. The simulated antenna can be pointed electronically, although the antenna does not physically move. In communications, beamforming is used to point an antenna at the signal source to reduce interference and improve communication quality*

In beamforming, both the amplitude and phase of each antenna element is controlled. This is used to adjust the side lobe levels. A beamformer for a radio transmitter shifts the phase and sets the amplitude for each element of the antenna array. A similar process is used for radio reception, but this time summing all the signals into one that has the desired directional pattern. In digital beamforming, the operations of phase shifting and amplitude scaling for each antenna element (and summation for receiving) are done digitally.

The latest beamforming techniques use adaptive antenna arrays. In adaptive beamforming, the processes described above are undertaken dynamically to maximise the quality of the communication channel. Hence the need for large amounts of computer processing power.

A smart antenna system typically comprises an array of four to twelve antenna elements that transmit and receive signals from a single base station. By focusing radio energy on specific users, this reduces interference from other users who may be accessing the same tower or base station installation. It also extends the range of the signal. With less interference, service providers can increase capacity on their portion of the radio spectrum by as much as a factor of 20 -depending on the application - giving more users a clearer signal.

Most of the **developments in smart antenna technology** have been largely restricted to military and government applications - to organisations capable of supplying the hardware and processing power capable of handling the complex algorithms necessary for beamforming. Few systems have, as yet, made their way into the commercial market.

Early smart antenna systems were designed specifically for military applications. These systems used directed beams to hide transmissions from an enemy; implementation required large antenna structures and time-intensive processing and calculation.

As attention turned to personal wireless communications, other issues became increasingly important. For example, it was evident that interference limited the total number of simultaneous users a network could handle – well before unacceptable levels of call quality were reached and blocking occurred. Since the narrow beams of the early (governmental) smart antennas created less overall interference, researchers began to explore the possibility of extending the use of smart antennas to reduce overall network interference in commercial wireless networks. The aim: to increase the total number of users a wireless system could handle in a given block of spectrum.

However, the hardware and processing power required to perform the complex calculations in the time available proved to be a hurdle – a hurdle too difficult for many to overcome. Even so, a few individuals and a few select companies successfully managed to introduce smart antenna technologies into wireless networks.

Early renditions of smart antenna technology, such as 'switched beam', 'multi-user switched beam' or 'shaped-beam' antennas, were relatively successful – but only to a limited degree. Today's systems using adaptive beamforming can accomplish the targeting with nearly pinpoint precision – giving a tremendous improvement in capacity and signal strength.

4. Adaptive beamforming – a breakthrough.

Adaptive beamforming is accomplished using software and advanced signal processing. The technology combines the inputs of multiple antennas (an antenna array) to form very narrow beams, which can be directed towards individual users in a cell. This creates significant gain and allows signals to be transmitted considerably further. The narrow beams eliminate extraneous interference, allowing many users to be connected within the same cell, at the same time, using the same frequencies. This delivers unprecedented spectral efficiency and capacity.

Smart antenna technology can be used in systems using all major protocols and standards: FDMA, TDMA, CDMA, FDD, TDD. The adoption of this technology into wireless networks takes advantage of the availability of low cost computer processing power to maximise spectral efficiency in wireless networks. Wireless network operators are now in a position to use extremely complex algorithms (eating up large amounts of processing power) to maximise capacity and accommodate increased wireless traffic in their networks.

The use of these systems provides greater capacity and offers increased performance (over standard antennas) because they can be used to customise and fine tune antenna coverage patterns to match the traffic conditions of the (wireless) network. They are also better suited for complex RF environments.

Furthermore, smart antenna systems provide maximum flexibility by enabling wireless network operators to change antenna patterns and adjust capacity, coverage etc, **dynamically**, to match the changing traffic or RF conditions in the network.

Comparisons with conventional systems:

Smart antenna systems are designed to achieve a number of benefits: augmentation of the signal quality through more focused transmission of the radio signals; increased frequency re-use which leads to enhanced capacity. The use of this technology thus overcomes many of the problems inherent in conventional wireless and delivers a level of performance significantly higher than any conventional WiFi or WiMax solution.

Not only do such systems offer greater range and coverage, more bandwidth and higher speeds, they are also able to support a larger customer base. This changes the whole economics of wireless networking, allowing the adoption of a more robust Business Model. **A smart antenna system therefore provides the ideal solution for wide area networking at community, citywide and regional level.**

Putting theory into practice

Beamforming has been around for nearly 10 years. In itself, the concept is relatively simple; putting theory into practice has proved to be much more difficult. It is only recently that the computer processing power has been available to carry out the complex algorithms required to implement beamforming on any affordable scale.

Understandably therefore, it is only recently that such techniques have started to emerge into the commercial world.

5. Symera: using smart antenna technology in wide area networks.

Symera has unique access to smart antenna technology, in particular the systems developed by ET Industries Inc[2] for the US Department of Defence. ETI's experience in developing state of the art wireless systems has lead to a number of breakthroughs in wireless technology – particularly in the field of beamforming and beamshaping, where ETI's president, Dr John Howard, is acknowledged as a leading authority. As a result, ETI has developed its own Wireless Integrated Communication System (WICS), a proprietary wireless broadband system that is WiMax compatible and has been developed to maximise throughput and utilise frequency bands as efficiently as possible.

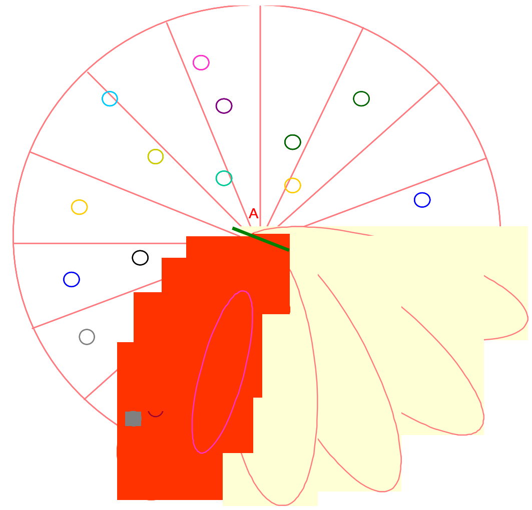
This technology is tried and tested, has been used in the most hazardous conditions by the US military for some 7 years and has now been released for civilian, commercial use.

Although these systems are comparable in many ways with WiMax – indeed they operate using the same IEEE 802.16 standards and protocols – it is the greater capacity and much better performance characteristics that allow these systems to stand out head and shoulders above the WiMax systems that are still emerging onto the market.

These systems have been used extensively by the US Department of Defence, by the US Air Force and by defence contractors such as Lockheed Martin. The technology has been subject to examination by the DTI and has been used in a number of systems in Europe, most notably at the Athens Olympics as part of the media communications infrastructure. It is now being considered for adoption by a number of municipal authorities both in the USA and Europe. It meets all the UK and European standards and there is a production line able to serve the needs of military and commercial customers.

The systems being installed by Symera use ETI's Multibeam**™** technology to spatially direct RF energy in multiple directions. This technology can now produce up to 144 sectors over a 360 degree area, while using only 4 physical antennas sited together.

[2] ET Industries Inc (ETI) is a leading edge, high technology company specialising in the design, development and manufacture of state-of-the-art wireless communication systems for terrestrial and terrestrial-satellite applications. With its strong R&D background and its in-depth experience producing systems for both military and commercial applications, ETI has been responsible for a number of breakthroughs in wireless technology.



Using conventional wireless technologies, such a system would require 144 physical antennas – a nightmare for set-up and alignment purposes. These systems also use frequency re-use, which also increases the number of customers that the system can support. The 48 beam systems offer a data throughput of 2.5 Gbps; the latest 144 beam systems can handle 7.5 Gbps.

A wireless network based on the Multibeam™ architecture is configured in much the same way as a traditional cellular network with strategically located base stations using a point-to-multipoint architecture to deliver services over a radius up to 50 kilometres, dependent upon frequency, transmit power and receiver sensitivity. In areas with high population densities the system will generally be capacity limited rather than range limited.

The beamforming solutions currently being installed allow one central base station site to transmit using up to 48 radio beams (4 x 12 beam sectors) at the full system data rate in 360 degrees up to distances in excess of 50km. Systems are available that offer up to 144 beams. The additional employment of adaptive interference suppression circuits means that any number of unwanted interfering signals may be eliminated.

The unique capabilities of the Multibeam™ antenna allow a magnitude increase in cell data throughput and thus subscriber capacity. In a 48 base-station site, it is possible to achieve up to 2.5Gbps of total data throughput by repeating the frequency allocation every 2nd beam. Each beam behaves as a wireless sector and is served by a base-station sector card delivering up to 54Mbps of data throughput.

Within the base station, adaptive modulation techniques are utilised by the wireless sector card to ensure that, on a subscriber-by-subscriber basis, link quality is maintained and overall signal power within the network is balanced and kept to a minimum.

5. Symera: network design

Symera is unique in the UK in that the company has developed a system architecture that combines a “best of breed” convergence of technology, software, content and applications into a seamless platform on a scale never before realized. While many of these elements are proprietary in nature, the marriage of these component parts into a fully integrated system is in its own right highly proprietary.

The proprietary aspect of this concept is based on successfully addressing a number of issues that are: 1) key drivers to the success of the enterprise, 2) have historically been barriers to entry to the business, and 3) have had a negative impact on the success of similar businesses.

Some of these factors are:

1. The expense and difficulty of constructing robust and seamless “carrier grade” wireless broadband networks;
2. The high recurring cost of “backhaul” capacity required to terminate customer traffic into Internet and voice (VoIP) gateways;
3. A lack of network and content security to prevent the interception of critical data by third parties;
4. The complexity of designing multi-tiered wireless broadband networks capable of supporting sustained traffic at high data rates;
5. The lack of effective end-user appliances that can accommodate “converged” media (voice, data, video);
6. The high cost of customer premises equipment (CPE) that effectively prevents low cost content and applications offerings in the residential marketplace;
7. .The lack of content and applications to support customer demand.

Symera’s network design adopts an approach where systems are engineered to function as multi-tiered wireless networks. Under this scheme many different wireless systems are integrated into a network, each designed to serve a specific requirement. Some of these systems are “off-the-shelf” while others are designed specifically for Symera’s own application. An exceptional characteristic of this concept is the integration of a number of “stand-alone” systems into a seamless network.

CPE costs

A major barrier to entry, as well as a primary factor in the failure of many broadband wireless deployments, has been the excessive cost of customer premises equipment. Typical CPE costs range from £200 to £400. At these rates it is very difficult to provide a cost effective service to lower income residential users.

Fortunately, over the years, costs have steadily declined. In Symera’s Eastserve project, the s of attention has been on serving this residential tier via the deployment of low cost local hubs, serving the needs of 20-50 subscribers.

Backhaul Costs

One of the other factors having a negative impact on the success of wireless deployment schemes has been the high cost of “backhaul”. Backhaul is the capacity necessary to transport customer traffic from the point of origin, through the wireless aggregation point, and back to an Internet or voice (VoIP) gateway.

Most wireless companies contract with the incumbent carrier (telco, PTT, etc.) for backhaul capacity. This cost has often proved to be so onerous that it has placed severe financial restrictions on the enterprise trying to offer a wireless broadband service. More than one wireless carrier has ceased operations due to the burden of backhaul costs.

Symera can overcome this problem by employing another tier of its multi-tier wireless overlay to transport traffic directly from the collection point to various gateway operations. Symerahas recently refined this model, and has produced its own wireless backhaul system.

Network Security

A major factor in wireless broadband transmission is network security. Traffic from most off-the-shelf wireless systems can be easily intercepted and decrypted by even the most unsophisticated of "hackers". As a result, wireless delivery has gained a bad reputation with companies involved in the transmission of sensitive or proprietary information.

The Symera portfolio of applications and content includes the highest level of non-military data encryption available. Secure virtual private networks (VPNs) can provide the customer with a level of security never before realized in a commercial environment. In keeping with the multi-tier nature of the company's architecture, security can be applied at various levels to satisfy all subscribers, from the casual residential "web-surfer", to applications-critical end-users such as banks, medical centers and governmental agencies. Previous deployments of this proprietary technology have borne out the success of this service in that, to date, not one VPN user has ever been "hacked" or had critical data stolen.

Sustained Network traffic

We believe Symera the first wireless broadband company to design and build networks capable of supporting sustained traffic. This is extremely important in that, until recently, most broadband usage was stochastic in nature. Stochastic traffic (such as web-browsing) is "burst-able" data. It occurs in "packets" that can be easily manipulated. Many such packets can be compressed to move about a network efficiently and cost effectively. This allows a network operator to place many subscribers on the network, much in the same manner as airlines "overbook" passengers with the knowledge that not all will show up at departure time.

However, with the recent introduction of "sustained usage" services, such as video streaming, voice over IP, video conferencing and distance learning, many stochastic network operators find themselves "over-subscribed" to the point where network throughput decreases, or in some of the more dramatic cases, the network "crashes". Symera has overcome this dilemma by designing its networks with "contention-rate" characteristics that allow for many more subscribers to access the network simultaneously, while at the same time accessing high data-rate sustained usage services. Even more importantly, Symera is able to accomplish this feat at a cost far below what would normally be incurred with similar deployment models.

End