ALTAI
Super WiFi

WIRELESS MESH ACCESS POINT VS. CELLULAR SMART ANTENNA BASE STATION

WHITE PAPER

Both cellular and mesh technology networks can be found in the market and in the following paragraphs we shall give a brief description of both technologies and draw a comparison between them. We shall see what the differences are and to determine which system architecture is more appropriate to use for municipal wireless network applications.

1. Wireless mesh network

Wireless mesh networking is mesh networking implemented over a wireless LAN. Mesh is a wireless co-operative communication infrastructure between massive amounts of individual wireless transceivers (i.e. a wireless mesh) that have Ethernet type capabilities.

This type of infrastructure can be decentralized (with no central server) for less scalable applications or centralized controlled for high scalable applications (with a central server), both are relatively inexpensive as each node needs only transmit as far as the next node. Nodes act as repeaters to transmit data from nearby nodes to peers that are too far away to reach, resulting in a network that can span large distances. Mesh networks are also reliable, as each node is connected to several other nodes. If one node drops out of the network, due to hardware failure or any other reason, its neighbors simply find another route. Extra capacity can be installed by simply adding more nodes. Mesh networks may involve either fixed or mobile devices.

The principle is similar to the way packets travel around the wired Internet — data will hop from one device to another until it reaches a given destination. Dynamic routing capabilities included in each device allow this to happen. To implement such dynamic routing capabilities, each device needs to communicate its routing information to every device it connects with, "almost in real time". Each device then determines what to do with the data it receives — either pass it on to the next device or keep it. The routing algorithm used should attempt to always ensure that the data takes the most appropriate (fastest) route to its destination.

The choice of radio technology for wireless mesh networks is crucial. In a traditional wireless network where laptops connect to a single access point, each laptop has to share a fixed pool of bandwidth. With mesh technology and adaptive radio, devices in a mesh network will only connect with other devices that are in a set range. The advantage is that, like a natural load balancing system, the more AP the more bandwidth becomes available, provided that the number of hops in the average communications path is kept low. However, as the mesh network grows bigger, the communication between AP in determining the routing will take up part of the usable bandwidth that can be used for data communication. Furthermore, as the number of hops is high, the aggregate time delay or latency will lead to poor performance for real time application like voice over IP.

There are three distinct generations of wireless mesh products today. In the first generation, also called as single radio ad-hoc network, one radio provides both backhaul and access, so wireless congestion and contention takes place at every node. Support is also very poor for video and voice applications because of excessive and varying delay across the network. In the second generation, also called as dual-radio mesh, one radio provides backhaul over multiple hops while another provided client access. While this offered a performance improvement in terms of bandwidth over first generation mesh, problems remain. With heavy user demand, there is still significant contention and congestion on the backhaul links. This limits the number of radio hops before another costly wired or fiber Ethernet connection is needed. Third generation wireless mesh products use two or more radios with multi-radio wireless backhaul. Third-generation mesh networking products can be called as multi-radio mesh, added with at least two physical radios for the backhaul. One backhaul radio is used to create a link to its upstream (nearer the wired source or "root") node. Another backhaul radio creates a link downstream to the next neighbor node. Unlike second-generation solution, these two radios may make use of different channels. Third generation mesh products are replacing previous generation products as more demanding applications like voice and video need to be relayed wirelessly over many hops of the mesh network.

No matter it is single radio or multiple radio mesh network, if the backhaul operates at the same frequency channel, it belongs to competing mesh architecture. As packets travel toward the Internet backhaul, they share the bandwidth at each hop along the backhaul path with other interfering backhaul nodes and contending neighbors. The bandwidth degrades at geometric progression away from the wired backhaul.

We can find in the market that all three generations of mesh products are available and the second generation is of majority use. Some vendors provide the second radio at options, while some vendors only offer third generation product at the most high end profile, the price of which is the highest as well. It is difficult to say which generation is the best, as this will depend on what your expectation is. For low density coverage without a very demand on real-time application, the first generation may be good enough in terms of cost effectiveness.

2. Cellular Smart Antenna Base Station

The cellular base station design makes use of smart antenna technology.

Smart Antenna

Smart Antenna (also known as adaptive antenna) refers to a system of antenna arrays with smart signal processing algorithms that are used to identify the direction of arrival (DOA) of the signal, and use it to calculate beamforming vectors, to track and locate the antenna beam on the mobile/target.

Smart antenna techniques are used notably in acoustic signal processing, track and scan RADAR, radio astronomy and radio telescopes, and mostly in cellular systems like W-CDMA and UMTS. This is why this type of WiFi base station is referred to as cellular base station.

Smart antennas have two main functions, namely DOA estimation and Beamforming.

DOA estimation

The smart antenna system estimates the direction of arrival of the signal, using any of the techniques like MUSIC (Multiple Signal Classification) or ESPRIT (Estimation of Signal Parameters via Rotational Invariant Techniques) algorithms, Matrix Pencil method or their derivatives. They involve finding a spatial spectrum of the antenna array, and calculating the DOA from the peaks of this spectrum. MUSIC involves calculation of eigenvalues and eigenvectors of an autocorrelation matrix of the input vectors from the receiving antenna array. These calculations are computationally intensive. Matrix Pencil is very efficient in case of real time systems, and under the correlated sources.

Beamforming

It is the method used to create the radiation patterns of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired, and nulling the pattern of the targets/mobiles that are undesired/interfering targets. This can be done with a simple FIR tapped delay line filter. The weights of the FIR filter may also be changed adaptively, and used to provide optimal beamforming, in the sense that it reduces the MMSE between the desired and actual beam pattern formed. Typical algorithms are the steepest descent, and LMS algorithms. Beamforming is a latest technology being used for various purposes.

Two of the main types of smart antennas include switched beam smart antennas and adaptive array smart antennas. Switched beam systems have several available fixed beam patterns. A decision is made as to which beam to access, at any given point in time, based upon the requirements of the system. Adaptive arrays allow the antenna to steer the beam to any direction of interest while simultaneously nulling interfering signals. Smart antenna systems are also a defining characteristic of MIMO systems, such as the proposed IEEE 802.11n standard.

Conventionally, smart antenna is a unit of a wireless communication system and performs spatial signal processing with multiple antennas. Recently, the technology has been extended to using the multiple antennas at both the transmitter and receiver, which is called especially as MIMO. As extended Smart Antennas technologies, MIMO supports spatial information processing, relative that conventional researches on smart antennas have focused on how to provide a beamforming advantage by the use of spatial signal processing in wireless channels. Spatial information processing includes spatial information coding such as spatial multiplexing and diversity coding, as well as beamforming.

3. Comparison of Mesh and Cellular Architecture

City-wide WiFi deployments across the globe are primarily using the mesh architecture, so the term “Metro Mesh” is commonly known nowadays. Mesh networking is a way to route the traffic between wireless nodes, the packets are transferred by hopping from node to node until the destination is reached. The reason of the mesh popularity is because of the ability to use one backhaul for a large number of APs, and also the site locations of the APs need not to be accurate enough as the APs can self-organize themselves to form a mesh network. However, there are high prices to pay for these simplicities.

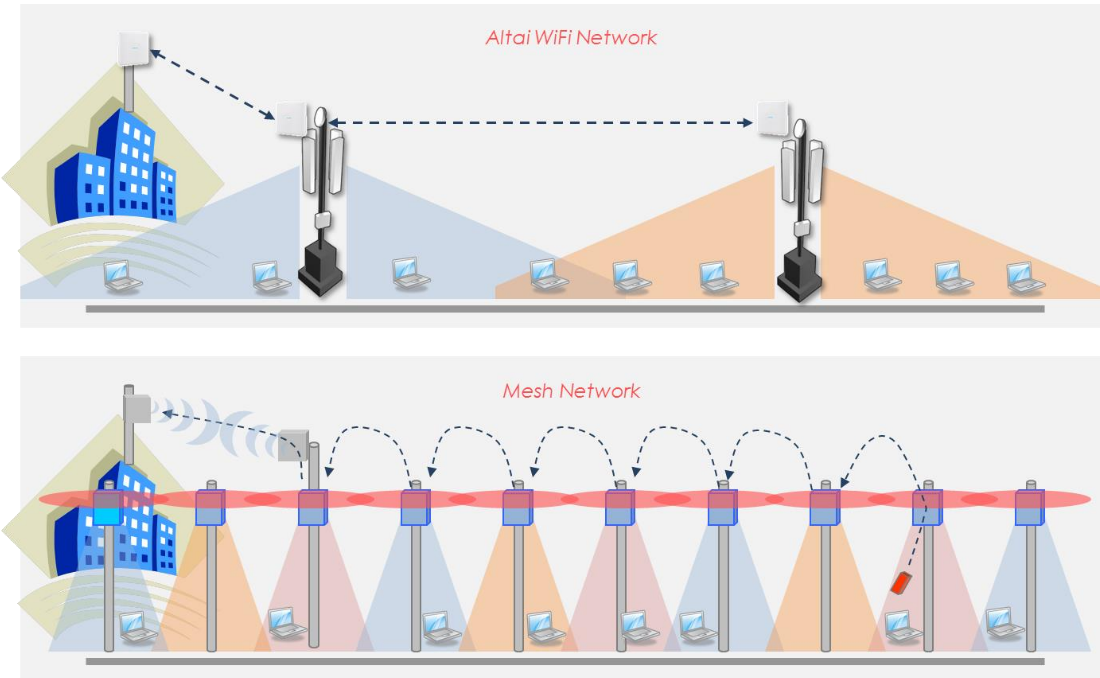
Mesh technology is originated from military applications as mesh networking moved from the battlefield to the service provider, enterprise and residential networking environments. The technology is developed to provide peer-to-peer connectivity on an ad-hoc basis, but it is not designed for multiple client terminals communicating with a serving radio in a client server mode. Today, Internet connectivity is needed more than local peer-to-peer connectivity. Data sources are primarily resident on the Internet, not on a peer. Also, to cover large areas in a cost-effective way, nodes may be placed further away from their eventual connection to the wired network, which implies the need for more hops within the mesh until the backhaul network is reached.

Most Mesh APs are equipped with dual-radio system for access and backhaul connectivity but single radio products still exist for low-end market. The mesh backhaul radios operate at the same channel and compete for bandwidth among themselves, this would bring down the aggregate network capacity. Some mesh APs have 3-radio, one for the access radio and the other 2 backhaul radios for ingress and egress functions operating at dedicated channels. It can be calculated mathematically that for a mesh network with merely 5 simultaneous clients per mesh node, both the single radio and the dual radio, single radio mesh architecture cannot provide usable bandwidth (for voice/video) beyond 2 hops. Practically speaking, if time-sensitive applications are to be used, 3-radio or multiple-radio mesh network is required. Latest technology on mesh backhaul operates on non-interfering channels which does not suffer from involuntary bandwidth sharing. The ultimate bandwidth available at the last access point from the wired backhaul can then be close to the bandwidth available using cellular architecture.

Apart from the bandwidth issue, there is another performance issue with the mesh architecture. The mesh routing algorithm makes a data stream to pass through a number of nodes to reach to the end user. The hop count problem will give rise to the high latency issue which makes the system hardly to support delay-sensitive applications.

Altai adopts WiFi cellular architecture such that the backhaul is usually located at the same access point that provides the access coverage to clients because of its large coverage capability, and thus imposing no latency on hopping. For larger footprint coverage requirement, one hop away from the end user by forming bridge link is usually enough. This master base station which provides the wired backhaul can link up to 4 slave base stations forming a cluster; with each slave base station only one hop from the master. This architecture can provide large coverage with minimum number of nodes and can support real-time VoIP and video streaming applications. The network architecture difference is shown in Figure 1.

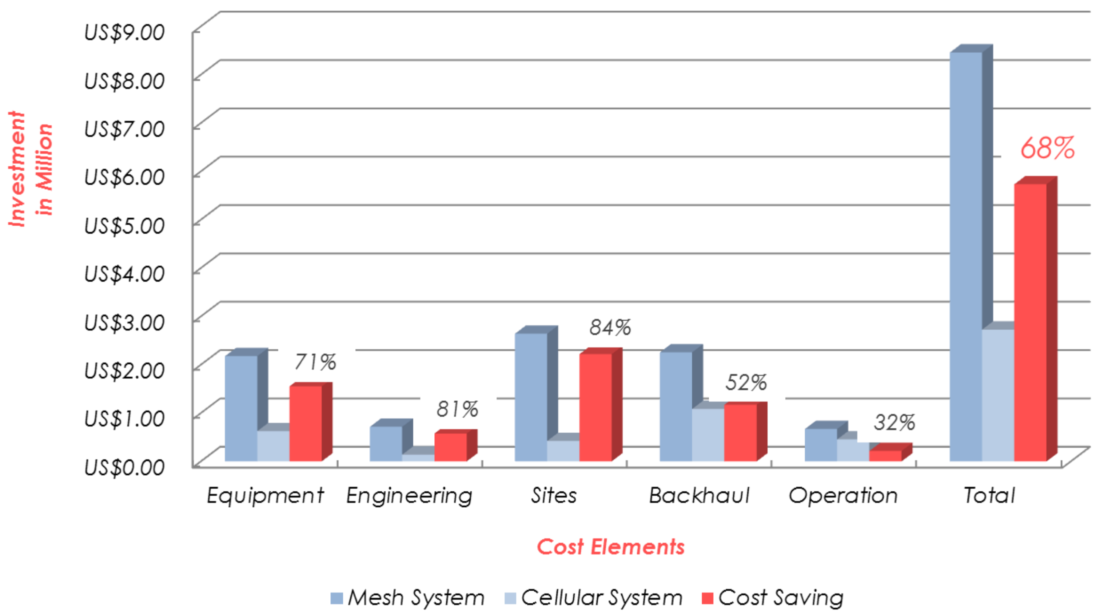
Figure 1: Altai WiFi Cellular vs. Mesh Architecture



Comparing the coverage capability, as a rule of thumb, 25 access points are required per km^2 for a mesh technology system. It is equivalent to 120 m NLOS (Non-Line-of-Sight) outdoor coverage radius per access point with some overlapping in between. A higher quantity is required if higher bandwidth is required in densely populated areas. It may go up to 100 access points per km^2. For cellular technology, a rule of thumb figure is 4 base stations per km^2, equivalent to 350m NLOS outdoor coverage radius per base station. It may go up to 12 base stations per km^2 for city area. Relatively speaking cellular WiFi base station can provide 3 times NLOS coverage radius and 6 to 8 times coverage area as compared to a mesh access point, no matter the measurements are made in densely or sparsely populated area, in LOS or NLOS environment.

In our white paper on "Cost elements of municipal WiFi network - How can you lower your investment costs?" using cellular base station architecture network can significantly lower the number of sites and hence the rental cost by 84%. It will also save 71% on equipment cost, 81% on engineering cost and 52% on backhaul cost. The total investment for a municipal wireless network can be saved by 68% using a cellular WiFi base station architecture system, details as per Figure 2 below.

Figure 2: Investment Cost Comparison for Municipal WiFi Networks



In conclusion, cellular WiFi base station architecture employing smart antenna technology can provide larger coverage per base station, higher bandwidth per user, lesser latency on real-time applications and lower total investment cost and payback period.