True Available Bandwidth

Myriad options lead to difficulty in assessment

The true available bandwidth of a radio system is always difficult to assess when dealing with the myriad options available. Often designers will sacrifice range for speed, knowing that adjustments may be made to ensure a reliable link. When connectivity is the primary requirement, the radio requires that the speed be limited to ensure sufficient link margin between the target and the device attempting to communicate.

Sensus is unique in the market in that it offers a robust, hardened enterprise class point-to-multipoint network design. Potential customers are often challenged with comparing network performance of this architecture as compared to a mesh implementation. Marketers of mesh systems often claim very high data throughput, and while this may be achieved on a single link between two close nodes, the actual realized throughput is far lower. When evaluating a mesh network, it is necessary to determine what is realistic. A mesh network claiming to achieve a high data rate of 1,200 kbps may do so but only for very short distances of 100 meters. To gain any network efficiency, the node must hop through several other nodes to an access point for aggregation and communication with a central control system. Alternatively, the mesh node data throughput may be lowered to gain a more real world range. When comparing to a licensed FlexNet® system operating at 57.5 kbps per channel an unlicensed mesh system would have to reduce its data throughput to less than 500 bps to achieve a similar range.

Mesh systems often attempt to talk about raw speed from one device to another while neglecting to properly provide details on the impact of moving through multiple radios. At each hop, the receiving radio must successfully decode the incoming message, determine the appropriate steps with regards to the incoming packet and if need be forward to the next device to move through the mesh. This hopping, along with node latency, impacts the true bandwidth available to a single point at any time. One additional factor is that the common use of the unlicensed spectrum band (ISM) dictates that the devices must run in half-duplex, and may only listen or transmit data at any point in time. To truly measure the data capability of a mesh network, it must first be determined how deep a given mesh is designed to operate, and then determine how many meshed endpoints will be serviced by a given access point. Below is a short evaluation that uses network throughput formulas that have been developed by mesh vendors like Silver Spring Networks.

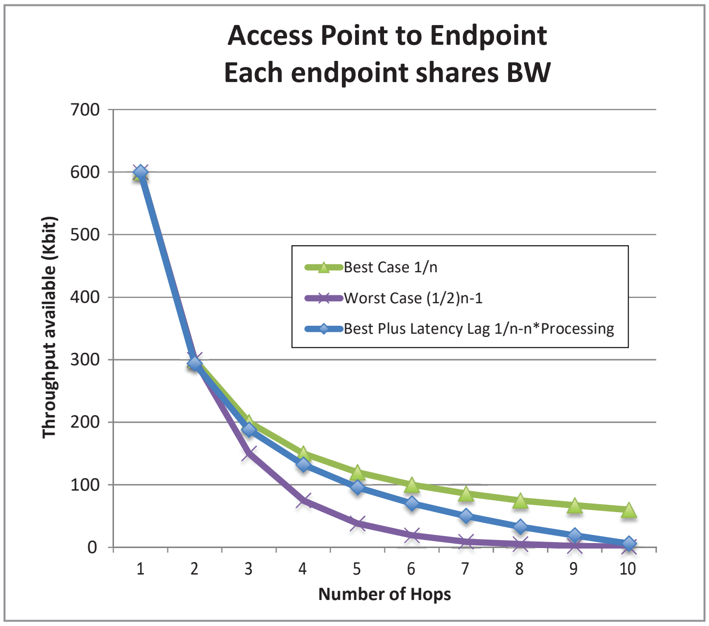
There are two common formulas used to determine the throughput in a mesh system. The first simply defines that each hop imparts a throughput that is inverse to the number of hops. That is, if there are two hops, the throughput is ½ and if there are three hops the throughput is 1/3, etc. While not overly accurate, for estimation purposes it does provide a quick, and usually overstated estimate of throughput. A more stringent algorithm estimates that at each hop, ½ of the available bandwidth is lost which aligns with the nature of a half-duplex network. Thus, at each hop, the bandwidth is multiplied by ½. So, for two hops ½, for three hops (1/2) * (1/2) leading to the formula of $(1/2)^{N-1}$ where N is the number of hops. Finally, the radios in the mesh themselves need to successfully receive a message and determine the appropriate measure of what to do with the message. This processing time is not negligible in a low power network and in fact can have a profound effect on throughput. The following tables summarize the above formulas.

AP Throughput Capacity		Number of Hops									
		1	2	3	4	5	6	7	8	9	10
Best Case	**1/n**	100%	50%	33%	25%	20%	17%	14%	13%	11%	10%
Worst Case	**$(1/2)^{n-1}$**	100%	50%	25%	13%	6%	3%	2%	1%	0%	0%
Best Plus Latency Lag	**1/n-n*Processing**	100%	49%	31%	22%	16%	12%	8%	6%	3%	1%

When applying to a real world system advertising to have a throughput of 1,200 kbps, the half-duplex nature of the network forces the first hop down to a realistic bandwidth of half of what is available. The following table provides real throughput values for a varying number of hops in the network.

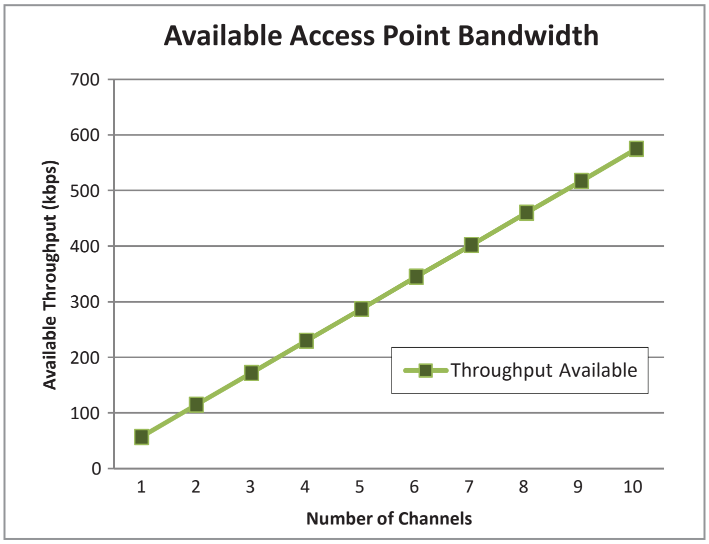
AP Throughput Capacity		Number of Hops									
		1	2	3	4	5	6	7	8	9	10
Best Case	**1/n**	600	300	200	150	120	100	86	75	67	60
Worst Case	**$(1/2)^{n-1}$**	600	300	150	75	38	19	9	5	2	1
Best Plus Latency Lag	**1/n-n*Processing**	600	294	188	132	96	70	50	33	19	6

By graphing the resultant data sets, it is very apparent that any extension of the mesh network results in a rapid degradation in available bandwidth to a single point.



Finally, since one channel is all that is available from a single collector, this bandwidth must be shared amongst all the endpoints. To achieve any reasonable RF (radio frequency) coverage (or range), the actual RF modulation is far lower than that which may be stated, as the noise that is permitted into the radio requires that the transmitter and receiver be in proximity such that it is not cost effective. Thus, the actual data rate used is far less to ensure a reliable link.

The FlexNet system operates at full duplex rather than half duplex as the mesh providers do, meaning FlexNet can both transmit (talk) and receive (listen) at the same time, nor does it hop. Thus, the stated available bandwidth and modulation is available to all endpoints at any time. In a scenario where 10 data channels are provided, the data rate for each channel is 37.5 kbps at all times and the downlink provides 20 kbps capability, so for each endpoint 57.5 kbps per channel is always available, with the 10-channel system providing 575 kbps throughput **at all times**.



To achieve a similar coverage and link reliability, a mesh system would require that it either reduce its data rate from the access point to a low enough data rate to ensure the same signal-to-noise ratio between the endpoint and access point or alternatively provide enough hops at a high data rate to provide the same coverage. Upon examination, it is realized that the result is the same and the effective true throughput for equivalent coverage on a mesh network is less than 25 kbps total, despite the advertised 1,200kbps bandwidth claims.

What this effectively means is that to appreciate the advertised bandwidth claims of a mesh network (from Silver Spring) field equipment (such as distribution automation devices) requiring the higher bandwidth would have to be placed very close, if not directly adjacent to, the access points, thereby limiting the number of hops required. While this may work for a limited number of devices, it does not deliver reliable deterministic performance across the entire architecture in the same manner as a true point-to-multi-point design as presented in FlexNet.

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