



# COMPARING OPERATIONAL AND COST EFFICIENCIES OF STAR AND MESH NETWORK TOPOLOGIES FOR BATTERY-POWERED AMR/AMI SYSTEMS

## SEEKING A SIMPLER NETWORK SOLUTION

With the advent of wireless technology, various models of topographical network architecture have evolved. This paper will focus on wireless technologies that relate to radio frequency (RF)-based automatic meter reading, commonly known as AMR, and advanced metering infrastructure, or AMI.

In the AMR and AMI arenas, two leading infrastructure models have emerged. The first of these is the star (a.k.a. “umbrella,” “single-hop,” and “point-to-multipoint”) network, where each endpoint transmits separately to a central hub at which data is collected, before being communicated on to the host. Another approach is the mesh (a.k.a. “peer-to-peer,” “multi-hop,” and “point-to-point”) network, so called because its many endpoint/repeater nodes resemble the knots in a net.

While each of these infrastructures has its own inherent design considerations, star systems are more preferable for AMR/AMI networks which use battery-powered endpoints. Key considerations will be further analyzed in this document.

## ARCHITECTURE COMPLEXITY

Let’s first look at the broad schematics of these two network models.

A star network, with its central hub and pathways from single endpoints, is fairly simple. Each Meter Interface Unit (MIU) communicates directly with the central hub or collector, which in turn communicates with the host. A mesh network, wherein each endpoint is a collector, is more complex. Because of the complicated algorithms required in a mesh network, the length of message sequencing varies greatly – from a couple of

minutes to over an hour. For field crews who must install, initialize, or service mesh-based MIUs, this variance means they cannot rely on “real time” transmission, creating a backlog that impinges upon operational efficiency.

## MAXIMIZING TRANSMISSION RELIABILITY WHILE PRESERVING BATTERY POWER

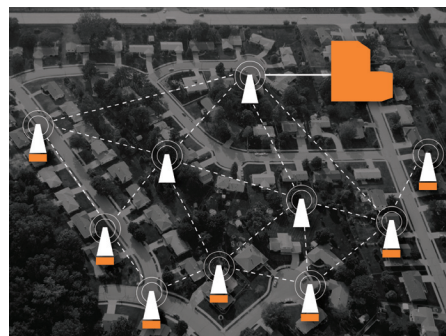
When an AMR/AMI mesh network relies on battery-powered endpoints to serve as communication conduits, endpoints originally meant to provide meter readings are often strained to serve in another capacity – especially in terms of battery usage. In addition, because of their limited transmission range due to limitations in output power to conserve battery life (when compared with that

of data collectors in a star network), more sensitive antennae and additional filtering devices are often needed for mesh endpoints. And while mesh networks are often touted as providing on-demand reads to endpoints at any time, this requires even more power and puts a further drain on endpoint batteries. Star networks enable scheduled reads – including time synchronized reads – that effectively extend, or at least preserve, battery life.

A challenge for battery-powered AMR/AMI systems is security; vulnerability to attacks and tampering is offset by a star network’s ability to provide measures such as “link-layer” security, but a mesh network is inherently more fragile. In a star network, when someone tampers with an endpoint to prevent meter readings from being transmitted, that single instance of tampering is limited to those individual readings. This is not the case with tampering in a mesh network. Here, that customer’s endpoint may act as a “repeater node” for the signals of other endpoints, whose inputs are compromised in a sort of domino effect. Even without direct tampering, the repeaters may fail, creating a “hole in the net” and losing reads. For the mesh network to recover those reads, it must either reconfigure another transmission pathway (“self-heal”) or add another repeater node to make up the difference. Because star networks do not rely on a series of endpoints to act as a conduit, self-healing is not needed.



*Star network*



*Mesh network*

## TAKING A LESS COSTLY APPROACH TO TAKE-OUT POINTS

That leads to another consideration in terms of scalability. It is true in general that mesh networks allow for both node repositioning and node addition. However, in the case of AMR/AMI, metering endpoints are not so easily

repositioned – they are often installed in meter pits or mounted on residences. And though adding a transmission node may increase signal strength, it also adds the greater likelihood of radio frequency interference with every “hop.” Past four or five hops, increasingly diminishing returns result. The endpoint cannot pass along any more data to other nodes downstream, becoming “clogged.” And unlike a star network, which can handle as much data as it can “hear,” the mesh network requires that this clogged repeater endpoint now become a destination node, or “take-out point” – with, for example, a GPRS modem equipped to relay the information over the long haul to a central database.

This means added overhead costs with each added take-out point. Although utilities may be reluctant to add the cost of a collector or two as take-out points (as part of a star network), they may not realize how quickly costs escalate by adding repeater nodes or even take-out points to the metering infrastructure of a mesh network. If a utility using a mesh network pays for cellular coverage, each new take-out point represents an additional monthly fee. If a utility does not have cellular coverage, additional take-out points will not even work. Complicating the issue further is that it is hard to predict what take-out points will be needed in a mesh network architecture, and the costs are just as unknown until deployment has already begun.

### THE BENEFITS OF STAR NETWORK COLLECTORS

The cost to implement collectors in a star system is initially more than that of the less-robust repeater endpoints and/or take-out points in a mesh system. However, one or two collectors can offer distinct advantages. First is simple installation; whereas a mesh

network uses a complex provisioning process in which MIUs must continually search and “listen” before establishing transmission paths – a process that can take up to an hour before confirmation can even take place – a star network allows for installers to test signal strength and verify communications in real time, saving man-hours and money.

Second, a star network collector allows for a stronger power supply than individual MIUs acting as nodes. For a comparable area, a mesh system must use many more repeater nodes on average, and those that are take-outs require greater power-and-communications coverage (WiFi, GPRS, Ethernet, etc.).

Third, using more than one star collector is a simple way to achieve operational redundancy and reliability that is equal to or greater than that of a typical mesh network (in the case of highly-redundant networks, as much as 80 percent of the AMR/AMI endpoint devices are heard by two or more collectors). In a mesh network, repeaters or take-out points in very dense common paths will not be redundant. Utilities may be surprised to learn that adding a star collector is not as difficult as they might think – the collector can be mounted not just on cell towers, but also on poles, buildings, water towers, and other spots with a suitable height.

The comparatively lower cost of overhead and maintenance is a fourth advantage. As mentioned earlier, the up-front cost of one or two star network collectors is a known variable, unlike the upwards-of-hundreds of possible additional take-out points (each needing GPRS connections) that may be needed in a mesh network. With two or more star network collectors, the likelihood

of a “single point of failure” is considerably less than that of the “multiple points of failure” that can occur in a mesh network. With a mesh network it is unlikely that the replacement of a single take-out node would fix a “hole” or prevent a utility from having to replace or upgrade scores of other endpoint failures. Pinpointing these multiple points of failure and addressing them successfully would be time consuming, logistically complicated, and costly, especially compared to the replacement of one or two collectors in a star system. At the same time, the high-powered star collector, with its more sensitive receiver, can better capture radio frequency signals bouncing off solid objects that might otherwise be lost. On a life-cycle cost basis, a star network can make a utility’s planning easier while saving money in the long run.

### CONCLUSION

While mesh networks may be suitable for applications where power is readily available, there are issues with implementing these networks in a battery-powered environment. Utilities utilizing an AMR/AMI system seeking to maximize reliability, scalability, operational efficiency, and their own budgets can do so by implementing a star network architecture model for their systems. By employing a simple schema where each endpoint is responsible only for its own data, a star network avoids data collisions and interference, reduces battery drainage, and avoids complicated “self-healing” pathway reconfiguration inherent in mesh network systems. Utilities utilizing two or more star network data collectors can often achieve the same or greater redundancies as those of mesh networks relying on repeater nodes and take-out endpoints, while realizing more predictive and less expensive life-cycle costs. 📶