Cloud-based IoT Battery Monitoring in Fiber Networks

IoT-BMS Enables Critical Decision Making for Fiber Network Operators
and Their Customers During Power Outages

The Battery Monitoring Imperative

History is rife with natural disasters that damage the electrical grid in countries around the world. Think earthquakes, hurricanes, tsunamis, wildfires, ice storms and the havoc that follows. Essential power services for residences and businesses alike are interrupted, sometimes for prolonged periods.

The United States has endured its share of devastating natural disasters with hurricanes, notably Katrina in 2005, recurring California wildfires, and the Texas ice storm in 2020, that all have severely damaged the electrical grid and telecommunications networks.

While there is no stopping Mother Nature, telecommunications network operators can take measures to ensure they are better informed of the operational status of their fiber optic and wireless networks when the primary commercial electric supply is either strained under heavy electricity demand periods or is outright damaged and service is cut off altogether.

In these brownout and blackout conditions, fiber and wireless networks can remain operational with power from standby batteries or backup generators.

When this happens, the first thing that network operators, and their customers, will want to know is: How much time do we have until the batteries run out? Did the generators start properly?

When a power outage occurs, the network operations center (NOC) first receives a battery on discharge (BOD) alarm from each site that has lost its utility power supply.

NOC managers generally know how much time they have based on the site design with a specified battery reserve time typically 8 hours or sometimes longer and diesel generator capacity, based upon the power load of the end equipment at the site.

What most NOCs lack, however, is a true indication of how much time actually is left until the batteries are completely discharged or empty. In other words, most remote sites lack a battery “fuel gauge.”

With any battery design, the energy storage capacity will deteriorate over time causing its specified reserve time to diminish without periodic preventative maintenance. Industry-prescribed battery maintenance generally involves cleaning battery terminal connectors, checking electrolyte levels on flooded batteries, taking voltage and current measurements, and “exercising” the batteries with controlled discharges.

With wireless and fiber networks continually expanding to meet growing traffic capacity demands, the number of wireless cell sites and fiber optic terminal and regeneration sites that require batteries (or fuel cells) are growing in numbers such that onsite battery maintenance is becoming time consuming and expensive.

Moreover, there is a growing shortage of power technicians needed to do all the required onsite maintenance. As a result, preventative maintenance intervals become stretched. Without regularly scheduled site visits, the condition of the batteries may change over time such that there is less reserve time than originally specified.

The LABRA Solution

Incorporating cloud-based Internet of Things (IoT) technologies into remote battery monitoring systems (BMS) provides near real-time visibility on the status of the batteries at any site, either on a temporary or permanent basis.

LABRA Technology, a privately held technology firm based in Delray Beach, FL has developed such a solution.

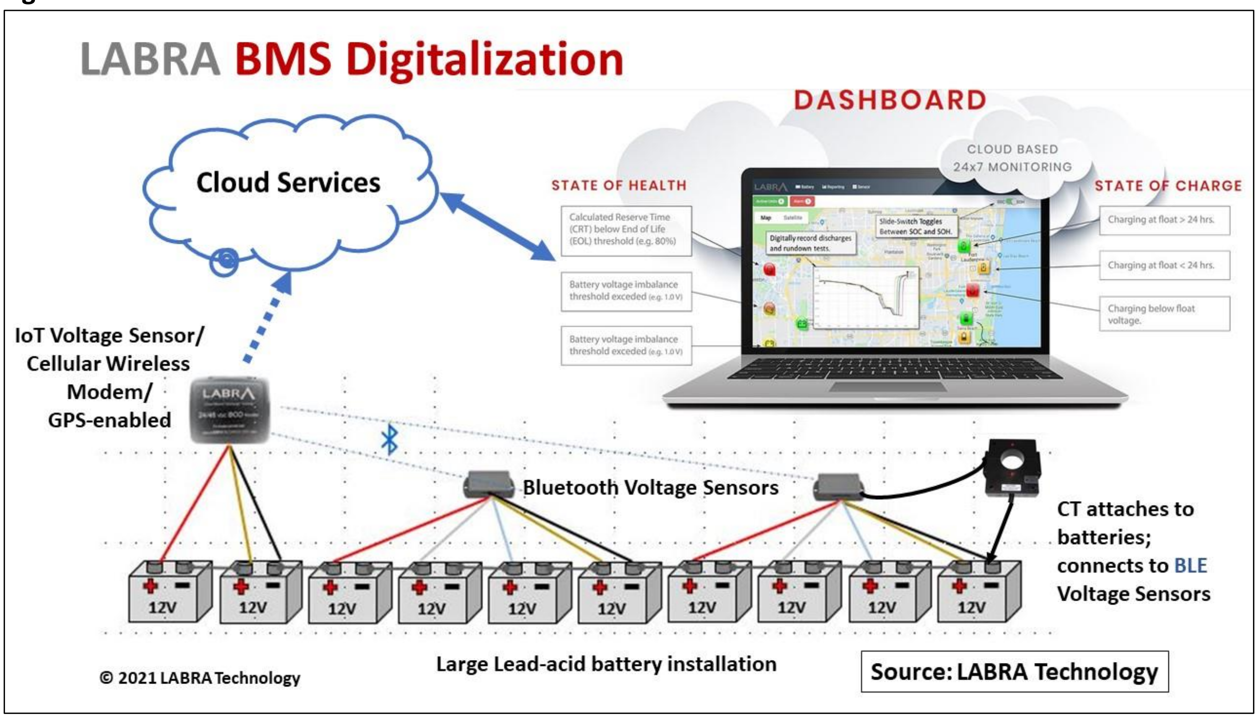
Here is how it works:

> LABRA's cloud-based IoT-BMS comprises several elements: a voltage sensor – basically, an IoT voltmeter - that is hard-wired across the positive and negative terminals of a -24 VDC or -48 VDC battery string, in optional or 2-wire or 5-wire configurations. (Figure 1)

> The IoT voltage sensor is enabled with a GPS beacon for identifying the site location and a cellular communications modem for establishing a cellular narrowband IoT (NB-IoT) connection to the cloud with the network operator's cellular carrier of choice.

Note that the sensor draws < 100 µA in Sleep mode and 100 mA in Awake mode. This rating does not include the voltage input card though, which is negligible by comparison.

Figure 1



> For large installations, one or more optional Bluetooth low energy (BLE) voltage sensors can be installed across battery strings to measure string voltages and transmit that data via a Bluetooth connection to the IoT voltmeter at distances of up to 30 feet.

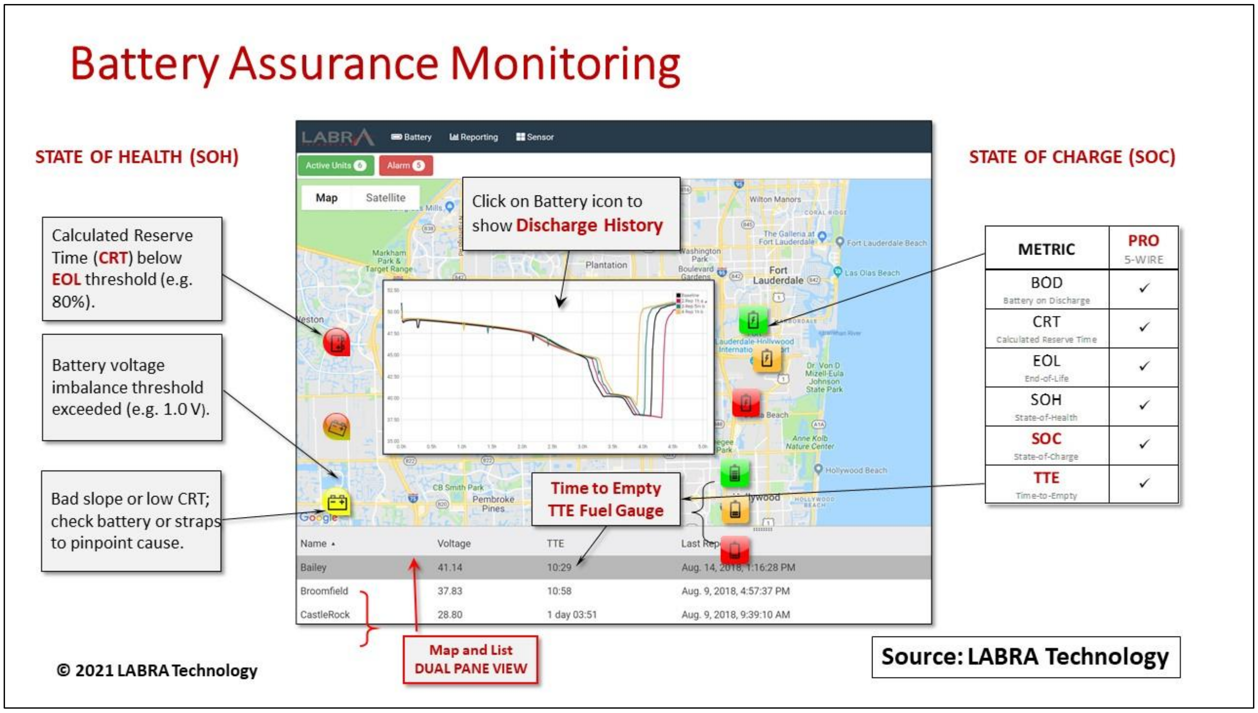
> If desired, an optional current transducer (CT) can be installed to take current measurements and transmit those readings to the IoT Voltmeter via the Bluetooth sensor.

> The IoT voltmeter samples the battery voltage at programmed intervals and uploads those data samples to the cloud where that data is stored and analyzed.

> When a battery on discharge (BOD) condition is flagged, a patented voltage-slope algorithm stored in the cloud calculates five more key battery metrics: state of health (SOH), state of charge (SOC), time to empty (TTE), end of life (EOL), and a new, calculated reserve time (CRT).

> These metrics are downloaded to a graphical user interface (GUI) dashboard in the NOC where the status of every battery plant in the network can be displayed, whether in normal, or in discharge state. (Figure 2)

Figure 2



> At that point, the NOC managers have an accurate picture of the battery status at each site. When the site is running solely on batteries, NOC managers will have sufficient information to make critical decisions as to whether to dispatch a maintenance crew, or to send a portable generator to maintain the most critical sites operational, or both.

Note that most large telecom sites have both battery and diesel generator back up. At these sites, batteries will discharge and maintain the site operational if the utility AC is lost until the diesel generator starts and produces an auxiliary AC feed that displaces the batteries which go back on recharge and serve as a backup until the utility AC comes back online. Many small telecom central offices do not have a standby diesel generator.

> The data displayed on the dashboard allows for a network wide view. At the same time, the dashboard allows NOC managers to drill-down to a particular region or geographic area, or even to a specific site. Alternatively, the data can be partitioned among many regional NOC managers for views on only their sites or shared with network customers, so that they too can know the status of their contracted services.

> The system was originally designed for lead-acid batteries but can be applied to different types of lithium batteries, either in a standalone application, or in a "mixed-mode" configuration with both lead acid and lithium batteries installed at the same site.

Application in Fiber Optic Networks

There are numerous applications for such an IoT-BMS. Monitoring stationary batteries in a telephone company central office or at switching/routing sites is a traditional telecom application.

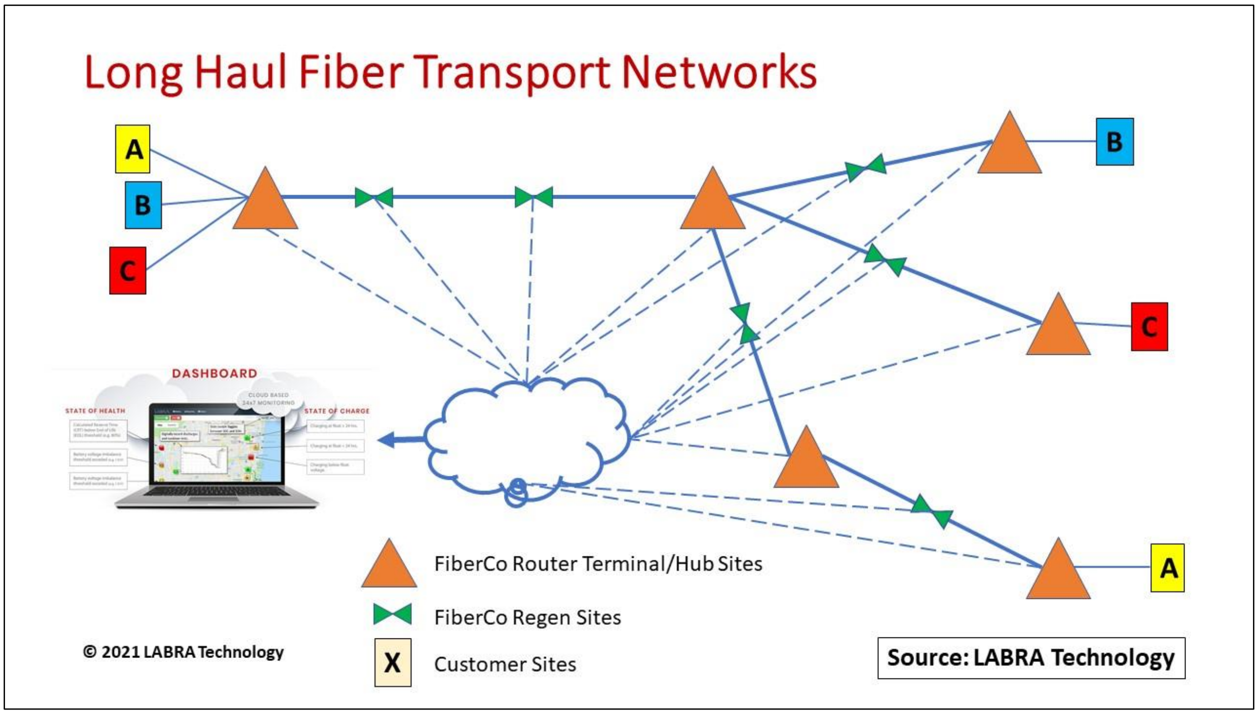
However, there are four mission-critical battery monitoring use cases involving fiber networks that are becoming significant including:

- Long-haul fiber transport networks with amplifier and regenerator sites along the route
- Metro fiber networks
- Wireless macrocell sites
- Wireless small cells

Use Case #1: Long-haul Fiber Transport Networks

Long-haul fiber networks can span hundreds or thousands of miles with multiple terminals, junctions or hubs, and regenerator sites. (Figure 3)

Figure 3



In these instances, the network operator shares its high fiber count cables, leasing dark fiber to multiple users under IRUs (Indefeasible Right of Use) contracts. These IRU customers typically will install their own fiber optic terminal equipment at their own sites but then utilize dedicated dark fiber strands. The fiber network operator runs and maintains the fiber routes between its terminals that can be many miles apart.

Terminals or junction/hub sites often have redundant dual -48 VDC power plants that can supply several thousand amperes (amps) with battery reserve capacity of up to 8 hours or longer.

Some sites may have backup power from alternatives sources such as diesel generators, renewable solar energy with storage, or fuel cells.

In a typical 400 or 800 Gbps DWDM long haul system, fiber network operators can deploy pluggable, digital, coherent optics (DCO) into router ports, selecting optics that can deliver signals over long distances without the need for intermediate regeneration, generally only amplification. Depending on the transport requirements, regenerator sites may be needed at distances from less than 100 miles to hundreds of miles apart.

Each regenerator site along a route typically will have a -48 VDC power plant of several hundred amps with several battery strings configured for 4- to 8-hour reserve.

Power outages can be localized, affecting just one or a few sites, or as was the case of the Texas ice storm in the winter of 2020, an entire region-wide network.

In this type of network configuration, an IoT-BMS can provide the near real-time battery status at terminals and intermediate sites along every route.

Use Case #2: Metro Fiber Networks/Fiber Rings

Metro fiber networks are designed to connect commercial and government buildings located in dense metropolitan and suburban areas to public or private clouds.

While the term fiber ring is often used, fiber cable is installed in conduits that follow street patterns. This way the fiber routes are designed to pass the greatest number of buildings along the path. In a large urban area, a metro ring comprises a few hub/core nodes and dozens of edge nodes that are close to connect points.

The fiber gets spliced to these edge nodes so that they reside on the ring for protection switching purposes. If the edge nodes are not on the ring, then they are connected via a single tail which can be isolated from the network if there is a fiber cut on the tail. The tail starts at the on-network site and can be connected to the on-network site by passive multiplexers or an add/drop channel at that on-network site. (Figure 4)

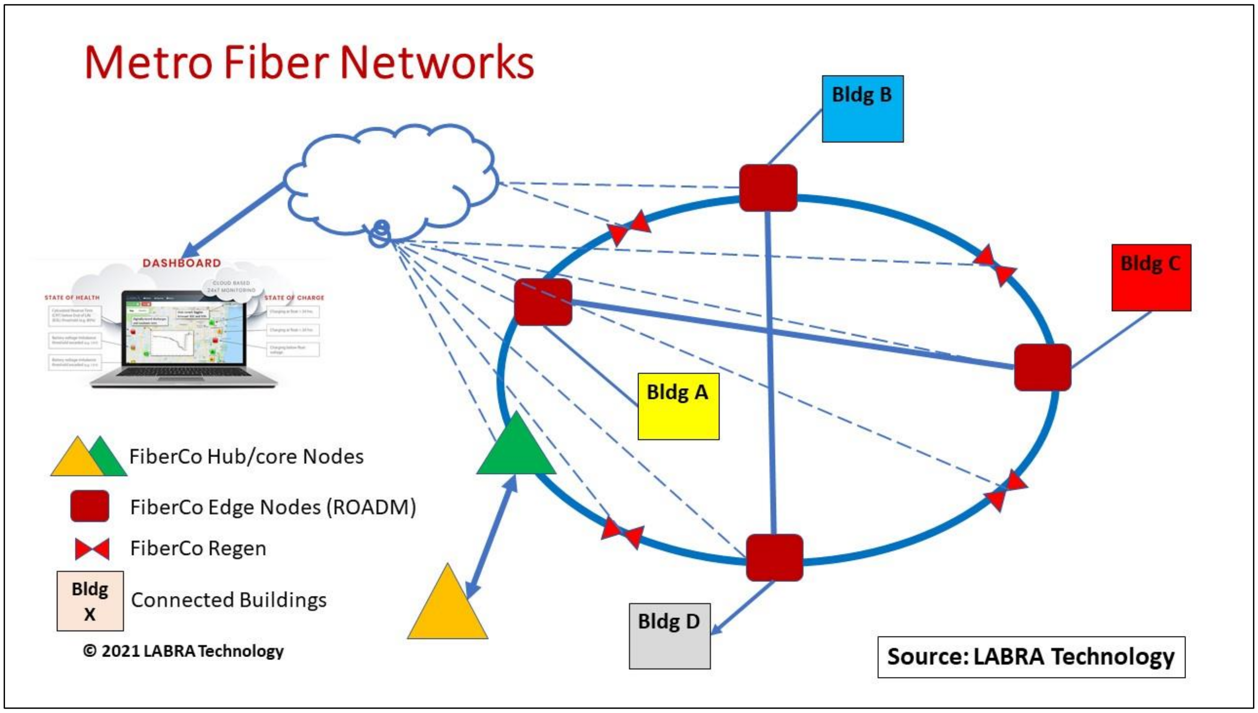
Depending on the capacity and reliability needs of the buildings being connected, making connections to the metro fiber ring typically are handled at edge nodes using active reconfigurable optical add-drop multiplexers (ROADMs) that transfer optical signals between the fiber ring and fiber terminals in the connected customer buildings.

Power backup is required to support active optical electronics at different points. Hub/Core nodes involve a lot of fiber optic terminal equipment for connections between the metro fiber ring and the long-haul transport network. These sites are powered by DC power plants of up to several thousand amps at -48 VDC with 4- or 8-hour batteries.

Edge nodes with ROADMs may involve an equipment cabinet or cable vault that has battery backup included. Like long-haul networks, regeneration sites may be needed at certain points depending on the density of the metro network and the fiber route-mile distances over which signals are carried. Such sites can have small DC power plants of several hundred amps at -24VDC or -48 VDC with 4 hours or more of battery capacity, generally the same battery backup time that is provisioned at an Edge or Core node.

As in long-haul network applications, use of pluggable DCOs at routers has proven to reduce power consumption dramatically by removing transponders in optical equipment and by removing the grey optic-optic hand off between the optical equipment and the traditional router port.

Figure 4



The designed battery reserve capacity at each of these sites will vary with the amount of equipment installed, the criticality of that site on the overall route, and the duration of battery reserve time required. If it is on the ring; it usually will have the same battery reserve time as the other Edge and Core nodes on the ring.

These terminal and intermediate sites are critical for the overall fiber network end-to-end performance. Where batteries are installed, the more critical is the need for an IoT-BMS.

Use Case #3: Cell Towers

Think of macrocells on towers as cash registers for the mobile network operators (MNOs). Macrocells provide wireless connections via the air interface to a customer's fixed (IoT sensors) or mobile (smartphone, laptop, tablet) devices, referred to as user equipment or UEs.

Communications signals are only "wireless" between UEs and the nearest cell tower. After that, these signals are carried over fiber terrestrial networks to other UEs or other cell towers, or to the MNO packet core and the Internet, prompting the phrase, "It takes a lot of wires to make wireless work!" In the current environment of escalation mobile data demand, those 'wires" are fiber optic cables. (Figure 5)

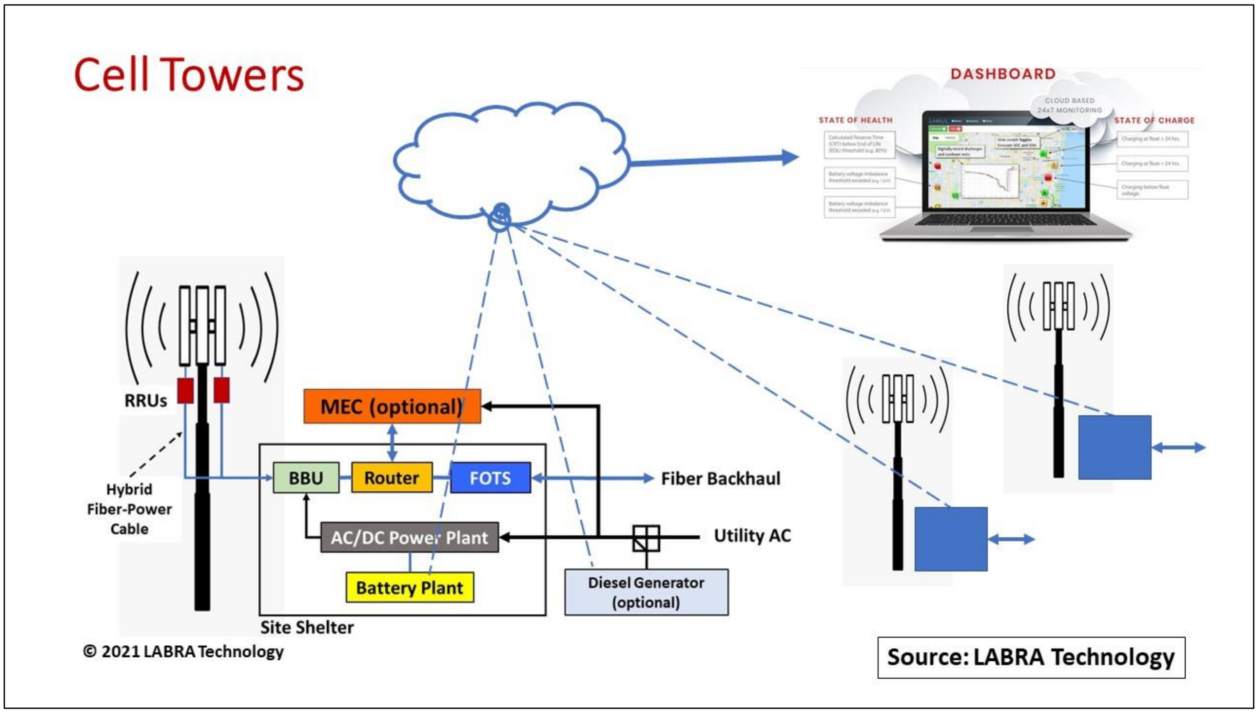
There is a lot of active equipment that requires electrical power installed at a cell site.

At the tower top, remote radio units (RRUs) are mounted next to passive antennas for RF transmissions to UEs. Increasingly, active antennas are being used in massive MIMO (multiple in-multiple out) applications, replacing passive antennas.

At the base of a tower in a hut or shelter are the baseband units (BBUs) that transmit data packets from the cell site router to the RRUs in a CPRI (common public radio interface) signal format over hybrid fiber-power cables.

On the network connection side, BBUs link to the cell site router and fiber optic terminal equipment for backhaul to the network core over a fiber network.

Figure 5



Fiber is the preferred backhaul facility where it is available to a cell site.

The shelter includes a -24VDC or -48 VDC power plant of several thousand amps and typically 8-hour batteries along with associated security and alarm equipment, and HVAC equipment.

Note that with the Open Radio Access Network (OpenRAN) architecture, the RRU is simply referred to as a radio unit or RU. The BBU is split into two parts – the distribution unit (DU) that interfaces with RUs via CPRI signal is converted to packets, and the centralized unit (CU) that performs Core functions. Generally, DUs and CUs will be located at an intermediate aggregation or centralized point, not at the cell site.

Where mobile applications require low latency, increasingly, multiaccess edge computing (MEC) equipment is being installed in containers at the tower base or in the same location where DUs are housed. If MEC is located at the tower with a BBU already in place, CPRI signals are converted to packets before MEC functions can be provided locally. A router is still required.

The need to keep these cell sites operational when power outages hit (assuming the tower itself is not damaged) is more critical than ever.

Reliability and predictability of backup power is critical. Power backup availability can be from batteries of different types (lead-acid or lithium), hydrogen fuel cells, diesel generators, and/or solar or wind renewable energy sources. The type of backup is determined by the amount of current supply needed to keep the site operational in the event of commercial power loss.

The need to actively monitor the batteries that protect RF equipment, baseband equipment, fiber optic terminal and MEC servers and routers is imperative.

Several operating groups have an interest in cell site battery status during a power outage.

First, the MNO itself needs to know how much power reserve capacity is left to keep the site on the air before the batteries fully discharge.

The tower company may be supplying the diesel generator and needs to know if genset start battery will work. Note that the generator start battery is distinct from any other site battery backup and needs to be charged separately for the generator to start. As such, the genset start battery may require a separate IoT-BMS.

The fiber network operator, whether the towerco or a third-party fiberco, needs to know whether the fiber optic terminals are operating and for how long.

Batteries installed at a cell site used to support different types of end equipment may be supplied by disparate groups. For instance, multiple carriers co-located at the site generally install and maintain their own DC Power plant and batteries for their own RRUs and BBUs in a separate cage within the hut or their own shelter at the base of the tower.

Diesel generators and onsite containerized MEC data centers can be supplied and maintained by the tower company.

Fiber optic terminals are the responsibility of either the tower company or a contracted fiberco.

An IoT-BMS can provide near real-time battery status once a BOD condition occurs. Regardless of who has responsibility for the different battery plants, battery status information can be shared among the different operating groups. Thus, a remedial response can be coordinated even though separate IOT-BMSs may be monitoring the respective infrastructure elements operated by the various organizations that share the site.

The good news is that a cell tower IoT-BMS application can be replicated across many sites in a region or even nationwide.

Use Case #4: Small Cells

A small cell is like a macrocell, only smaller. A small cell comprising a radio and antennas (either an omni antenna or a 3-sector array), is typically mounted on “street furniture” (telephone pole, utility pole or streetlight) and requires a power feed and fiber for backhaul. (Figure 6)

Small cells typically are installed as a node on a fiber optic route running through downtown areas and along suburban streets.

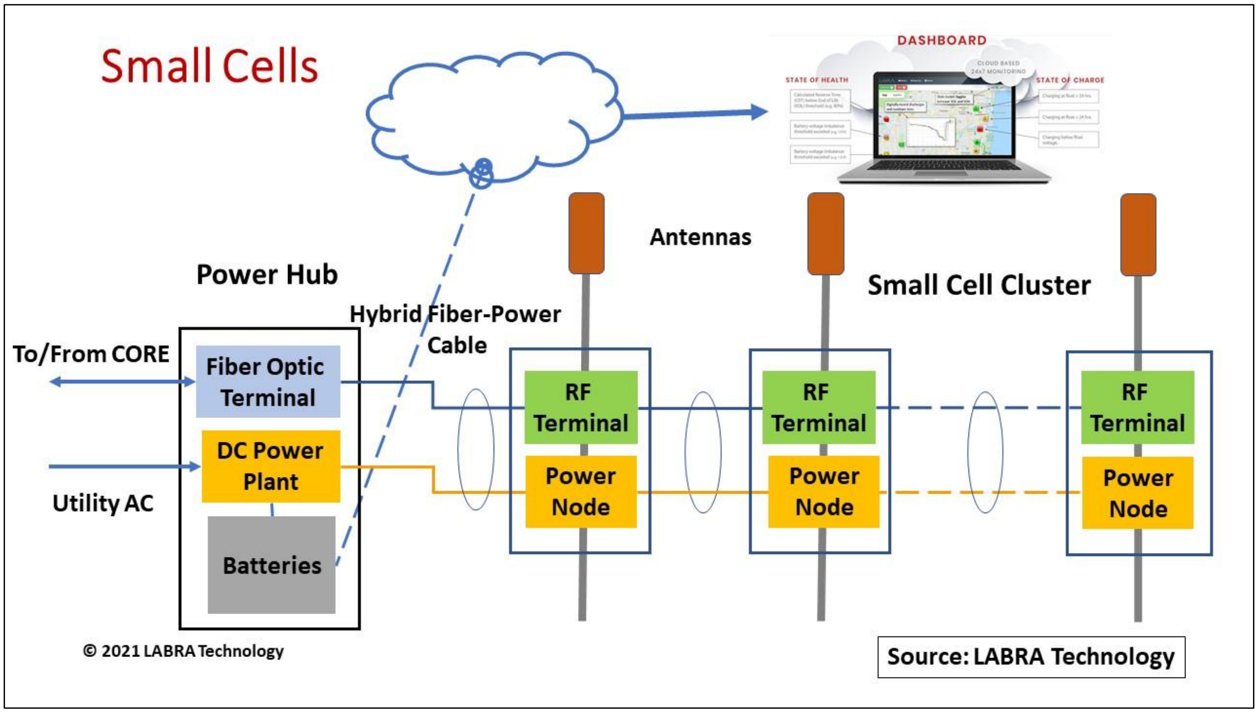
The rise of small cell deployments is driven by 1) the need by MNOs to densify their networks by pushing antennas closer to customers to support high-speed, mobile data applications such as Internet access, gaming, and video streaming, and 2) the use of high-bandwidth, millimeter wave frequencies that propagate only over short distances, typically less than 1 km.

Consequently, the number of small cell deployments is proliferating with tens of thousands a year across the wireless industry.

Like macro cell sites, these small cells require a power source and a fiber optic connection for backhaul. Where a dedicated fiber connection to every small cell is not feasible, some MNOs are utilizing integrated access and backhaul (IAB) technology or repeaters to get the RF connections back to the MIMO or RRU/BBU source.

Depending on the location, small cell power connections vary. Some small cells operate only on metered AC power. At other sites, the metered AC power is converted to DC power, with or without battery backup. Without backup, however, small cell will go off the air during a power outage.

Figure 6



Alternatively, power for clusters of small cells can be line-fed from a common source, referred to as a power hub.

In the latter scenario, an equipment shelter serves as a terminal for a fiber route that connects 25-30 small cell nodes. The hub houses the fiber optic terminal equipment that connects the small cell cluster on the fiber route to the larger fiber backbone network.

A DC power plant of several thousand amps with batteries is installed in the hub to power the fiber optic equipment and the small cells that are fed by a hybrid fiber/power cable along the fiber route. Battery reserve time can be 4 or 8 hours, depending on the MNO and the market being served.

Here battery backup is critical to maintain both fixed and mobile wireless services to residences and businesses along the fiber route.

An IoT-BMS at a hub site can provide both the MNO and the small cell provider, such as a tower company or fiberco that supplies the fiber, with near real-time battery status when the utility power goes out.

Conclusion

Battery monitoring is imperative to provide NOC managers with the status of the batteries, whether in normal or discharge state, at each site in their network. More importantly, with a diminishing pool of qualified power technicians, an IoT-BMS application allows network managers to shift battery operation from a preventative maintenance to a predictive maintenance mode.

An IoT-BMS provides near real time visibility on battery status in a cost-effective manner.

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