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The Pitfalls of Cellular AMI

Cellular networks offer numerous advantages for various applications, yet when utilized for water utility AMI systems, they present certain risks. The following aims to highlight crucial considerations for utilities contemplating cellular networks as the foundation of their communication systems.

Part 1 - Network Longevity – Loss of 44% Device Life

Cellular networks predominantly cater to consumer demands, with an escalating reliance on devices, connectivity, and heightened expectations for bandwidth, services, and security. The network's architecture and usage are heavily influenced by these evolving consumer needs. Additionally, the spectrum allocation overseen by the FCC, spanning consumers to critical services like defense and emergency response, further shapes network development. The limited availability of spectrum necessitates providers to optimize their allocations to meet diverse service and security requirements, often incurring significant costs.

These dynamics fuel the progression of cellular networks and device interfaces. As depicted in *Fig. 1 Network Timelines*, networks typically operate for 20-25 years. However, with the continuous advancements in applications, security protocols, analytical capabilities, and cost efficiencies in devices, the pace of network evolution is expected to accelerate.

The availability of a network is a critical value proposition of useful device life in an AMI network. The typical AMI communication battery device life is 20 years, but this can be significantly constrained by the network availability and dependent upon the deployment schedule with respect to the network lifecycle. In general, it is difficult for manufacturers to design, test, and ramp up manufacturing of the communications module within a few years. This suggests that, on average, a cellular device may have about 15 years of useful life, and those introduced in later years might have slightly shorter effective lifespans.

Fig. 2 Cellular Useful AMI Device Life illustrates the useful life of a 10,000-services AMI deployment with an initial deployment life of 15 years. Included is the introduction of a new device for next-generation networks. The total useful life (devices * years) is combined in the last column.

Compare this with the radio frequency lifespan in *Fig. 3 Radio Frequency Useful AMI Device Life*. The net difference is 44% more useful life with radio frequency units. Admittedly, there will be variances in specific use cases; the above case illustrates a typical scenario.

The cellular consequences include not just a decrease in useful life but also an increase in device cost. Furthermore, the total cost of ownership will rise due to additional labor for installation and disposal expenses. These typically far exceed the costs associated with collectors and maintenance.

Many will argue that the future promises innovations such as programmable SIMs and migratory capabilities. While this may be true, information regarding product availability and cost has yet to be provided. Moreover, current devices are generally not upgradeable for such migrations, resulting in a limited lifespan that depends on network availability.

Figure 1 - Cellular Network Timelines

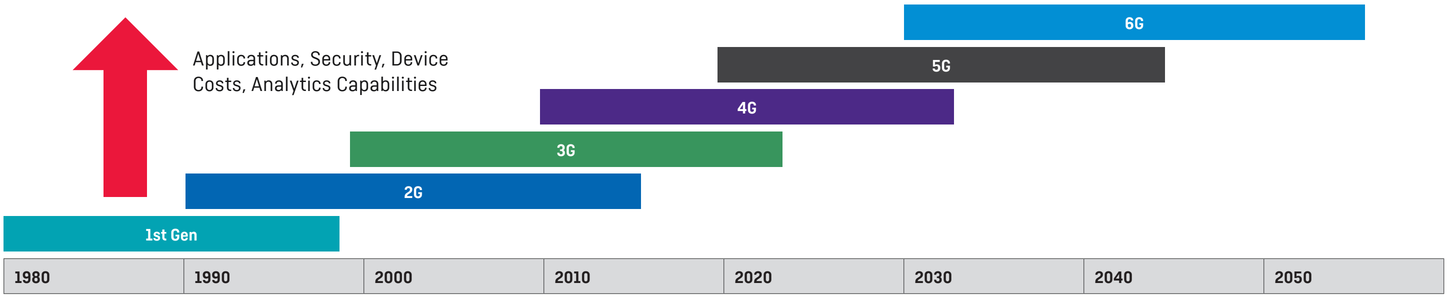


Figure 2 - Cellular Useful AMI Device Life

Cellular

Deployment Year	Units Deployed	Total Units	Useful Years	Total Useful Years
1	10,000	10,000	15	150,000
2	200	10,200	14	2,800
3	204	10,404	13	2,652
4	208	10,612	12	2,497
5	212	10,824	11	2,335
6	216	11,041	10	2,165
7	221	11,262	9	1,987
8	225	11,487	8	1,802
9	230	11,717	7	1,608
10	234	11951	6	1,406
11	239	12,190	5	1,195
12	244	12,434	4	975
13	249	12,682	18	4,476
14	254	12,936	17	4,312
15	259	13,195	16	4,140
16	264	13,459	15	3,958
17	269	13,728	14	3,768
18	275	14,002	13	3,569
19	280	14,282	12	3,361
20	286	14,568	11	3,142
				202,149

Useful Life in Years: 1–40

Telco Sunset

Telco Sunset

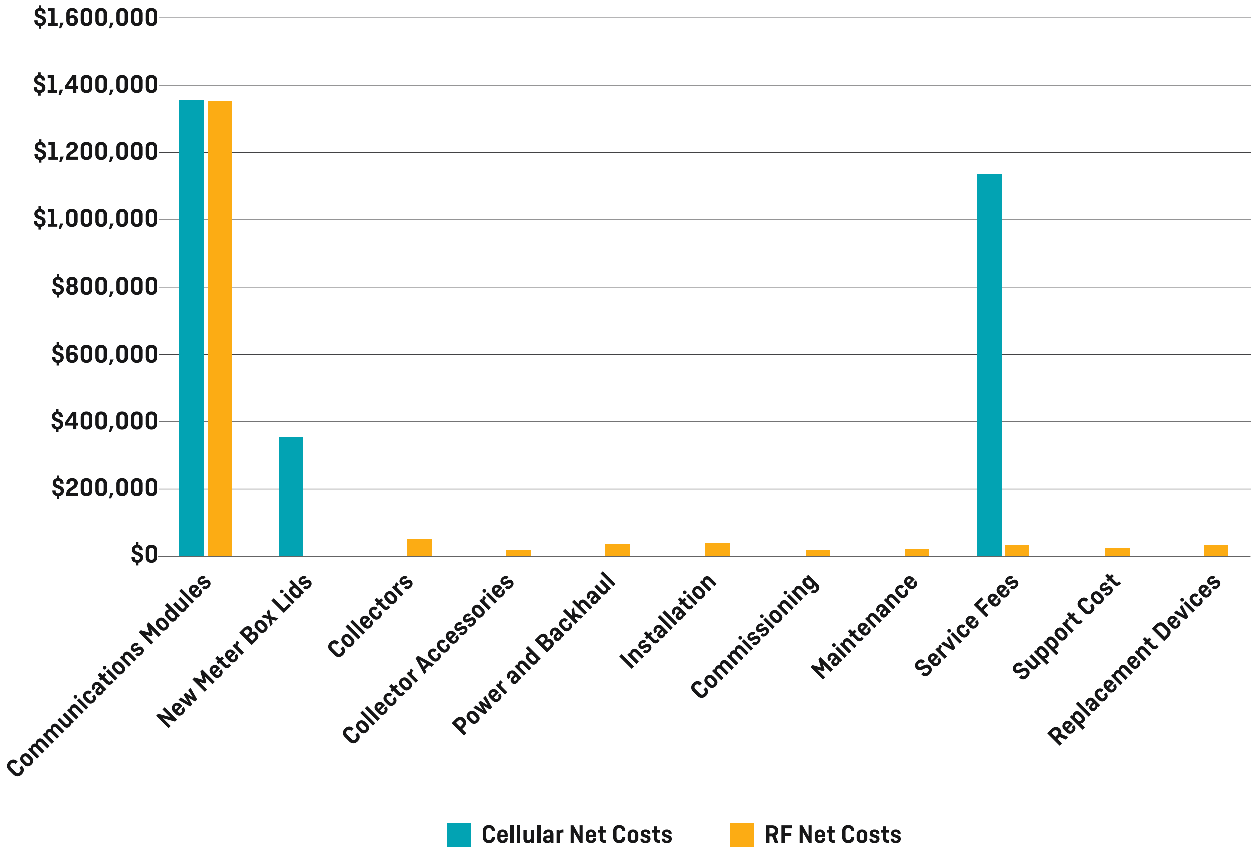
New Generation Comms

Figure 3 - Radio Frequency Useful AMI Device Life

RF Deployment Year	Units Deployed	Total Units	Useful Years	Total Useful Years
1	10,000	10,000	20	200,000
2	200	10,200	20	4,000
3	204	10,404	20	4,080
4	208	10,612	20	4,162
5	212	10,824	20	4,245
6	216	11,041	20	4,330
7	221	11,262	20	4,416
8	225	11,487	20	4,505
9	230	11,717	20	4,595
10	234	11951	20	4,687
11	239	12,190	20	4,780
12	244	12,434	20	4,876
13	249	12,682	20	4,973
14	254	12,936	20	5,073
15	259	13,195	20	5,174
16	264	13,459	20	5,278
17	269	13,728	20	5,383
18	275	14,002	20	5,491
19	280	14,282	20	5,601
20	286	14,568	20	5,713
				291,362
			Additional Unit Life - Years	89,214
			Additional Unit Life - %	44.1%

Useful Life in Years: 1–40

Figure 4 - Network Lifecycle Costs



Part 2 - Operating and Capital Costs-76% More Expensive

One of the attractive aspects of cellular is the lack of capital costs for infrastructure. To truly understand the total cost of ownership of a cellular system, one must expand the overall considerations to look at all costs over the lifecycle of the equipment. Typically, utilities use a twenty-year useful life depreciation model for these types of assets, which aligns with the intended useful life of most hardware.

Over this twenty-year period, one should consider the following types of costs: hardware, installation, commissioning, accessories, maintenance, service fees, and other support costs. Prudent evaluation of costs by each type is detailed with a comparison of typical radio frequency AMI solutions based upon a 10,000, services system.

The example shown in *Table 2: Lifecycle Costs* is intended to illustrate the types of expenses and some typical evaluations – values may change with respect to utility size, vendors, local costs, and geographies. Utilities are encouraged to evaluate the options based on their service territory, vendor pricing, assets, and options.

Initial Costs (Hardware, Accessories, Installation and Commissioning)

In general, most of the initial capital expense of either a cellular or RF system is in the communication device at the meter location. For the sake of simplification in this example, let's assume the device costs of cellular and RF modules are the same, and we'll set the cost at $135 per device for each. Now, let's compare the capital costs involved in each system. Because cellular systems utilize existing telecommunications infrastructure, there is no cost to the utilities to set up this hardware. However, cellular modules often require that existing meter box lids be replaced with composite lids. This cost is approximately $35/unit.

The major difference in the RF system is in the cost for the collector at approximately $12K/unit. Assuming a system requires four collectors to cover the service territory, the lifecycle costs are $48k. These collectors will also require installation, antennas, arrangements for power, and backhaul and commissioning costs, which are pre-existing for most cellular networks. Even though most utilities can utilize existing assets with power and potentially backhaul services, there is likely to be some cost for these expenses. For these purposes, we can estimate these additional initial costs to be $104K. At this point, our comparison costs are $35/meter to initiate a cellular network and $152K to initiate an RF network. $152K would be the cost of 4,343 composite lids.

Operations and Maintenance Costs (Parts, Support, Service, Maintenance)

Cellular providers are quick to point out that their offerings require maintenance costs, parts, and support costs. It is true that no separate line items are needed for these items, but they are part of the service fees associated with using the cellular network. These are often sold as Network as a Service (NaaS) or part of Software as a Service (SaaS). These fees are made to seem small on a $/month/service basis. For the purposes of our comparison, let's assume a year-one cost of $0.35/service/month and a 3% annual price escalation. This equates to $42,000 in expenses for the cellular system in year one. Considering the escalation, these fees can rise to over $73K per year. At this rate, the fees are roughly equivalent to the cost of the original communication device themselves, with a lifecycle cost of over $1,128,556. See *Table 1 Cellular Service Costs* for details.

With RF systems, the utility will incur costs for parts, support, and service. However, the systems use mature technology, and the amount of work and risk is small. Think of this like your car radio. How many times has it failed you? RF systems may also incur some equipment replacement costs during the 20-year period. We estimate this potential cost at around $8K each for an additional outlay of $32K. Some maintenance and support may be required as well. Often, these services are available from local distributors for a reasonable rate and do not require staffing, equipment, or training. For these purposes, we can estimate the expense at an additional $44K over the useful life. Unlike cellular systems, there is no service fee to telco carriers for the cellular network. There may be additional backhaul costs, which are typically small and estimated to be around $33.6K over the life expectancy of the system.

In summary, as detailed in *Table 2, Lifecycle Costs*, an RF system has significant savings compared to a cellular system. The RF system lifecycle costs are approximately $1.61M as compared to the cellular system at $2.83M or a 76% increase in costs for a cellular system. Note: This does not include software costs.

Utilities should perform their own specific evaluations and look at the entire cost of ownership and the benefits of an AMI system when selecting a provider.

Table 1 - Cellular Service Costs

Price Escalation/yr = 3%

Year	Service Fees/ Unit/Month	Service Costs
1	$0.35	$42,000
2	$0.36	$43,260
3	$0.37	$44,558
4	$0.38	$45,895
5	$0.39	$47,271
6	$0.41	$48,690
7	$0.42	$50,150
8	$0.43	$51,655
9	$0.44	$53,204
10	$0.46	$54,800
11	$0.47	$56,444
12	$0.48	$58,138
13	$0.50	$59,882
14	$0.51	$59,882
15	$0.53	$61,678
16	$0.55	$63,529
17	$0.56	$65,435
18	$0.58	$67,398
19	$0.60	$69,420
20	$0.61	$73,647

Table 2 - Lifecycle Costs

Item	Cellular			RF		
	Units	Unit Price	Net Costs	Units	Unit Price	Net Costs
Communications Modules	10,000	$135	$1,350,000	10,000	$135	$1,350,000
New Meter Box Lids	10,000	$35	$350,000	-	$ -	$ -
Collectors	-	$ -	$ -	4	$12,000	$48,000
Collector Accessories	-		$ -	4	$4,000	$16,000
Power and Backhaul	-		$ -	4	$9,000	$36,000
Installation	-		$ -	4	$9,000	$36,000
Commissioning	-		$ -	4	$4,000	$16,000
Maintenance			$ -	4	$5,000	$20,000
Service Fees			$1,128,556	4	$8,400	$33,600
Support Cost			$ -	4	$6,000	$24,000
Replacement Devices			$ -	4	$8,000	$32,000
			$2,828,556			**$1,611,600**
					Savings	46%
					Expense	76%

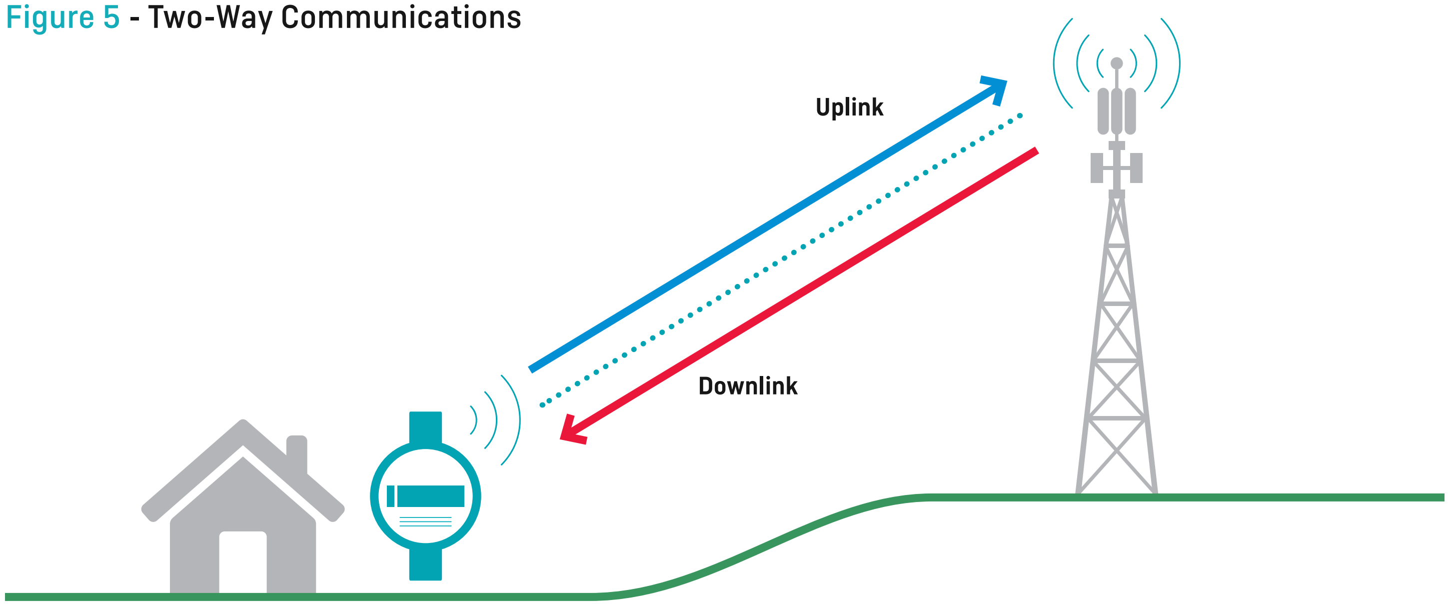
Part 3 - Coverage: Not in your control

One of the most attractive features of cellular systems is that the infrastructure is already in place. The challenge, however, is that key performance indicators such as coverage area, signal quality, and signal strength depend on current smartphone technology and consumer usage patterns. The design parameters for this scenario typically require the consumer device to be 1 meter above ground without any interference from metal boxes and capable of moving between bands using roaming provisions. In contrast to consumer cellular networks, an AMI system would operate on a defined band, such as 4G LTE-M, and would be confined to that band. The cellular AMI system would not be able to switch to the EDGE, 5G, LTE, or Nb-IoT bands. Similarly, the AMI device is likely to be located in the ground, with potential interference from metal boxes. Therefore, cellular network performance can vary significantly, as height and metal represent significant impacts. To mitigate some of these issues, many vendors require the meter box lids to be replaced (another hidden cost). The key point is that neither the coverage maps published nor your smartphone experience can be considered reliable indicators of communication capabilities.

If a person were to experience a lack of coverage with a smartphone, they can simply move to a more responsive area and return to expected service levels. With a water meter, the location is set, the bands are limited, and the height is static. In other words, there is little to no opportunity to change the signal quality or strength. The only means to recover from the lack of connectivity is to have the carrier put up another cellular collector or to read the device with some other means, either visually or drive-by. These are all expensive options that require the utilities to consider and maintain various levels of service for different customers. With radio frequency and other communications means, the ability to add infrastructure in locations to optimize performance and service levels is becoming more affordable.

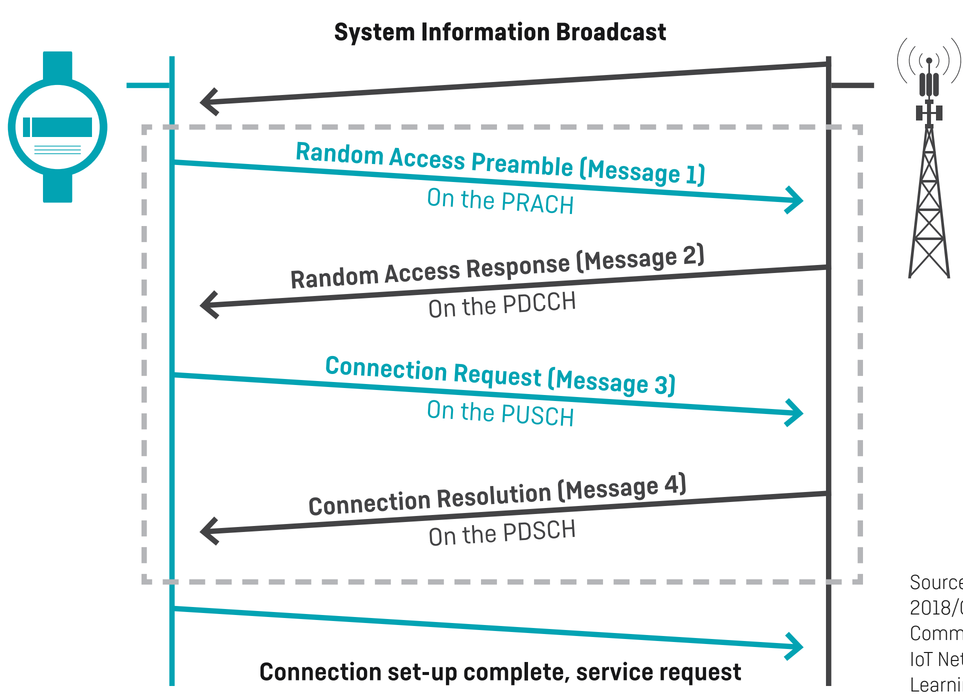
Part 4 - Device Life and Communications Capabilities are Limited

Figure 5 - Two-Way Communications



One of the largest differences between your smartphone and water meter communications modules is the ability to recharge the phone's battery. With AMI, there is no practical way to recharge the batteries, so the devices must manage power to provide the desired useful life. With cellular communications, the devices typically establish a point-to-point handshake. This handshake requires a significant amount of "on" airtime, which requires more power resources and is typically more power-intensive than the actual data payload of the transmission.

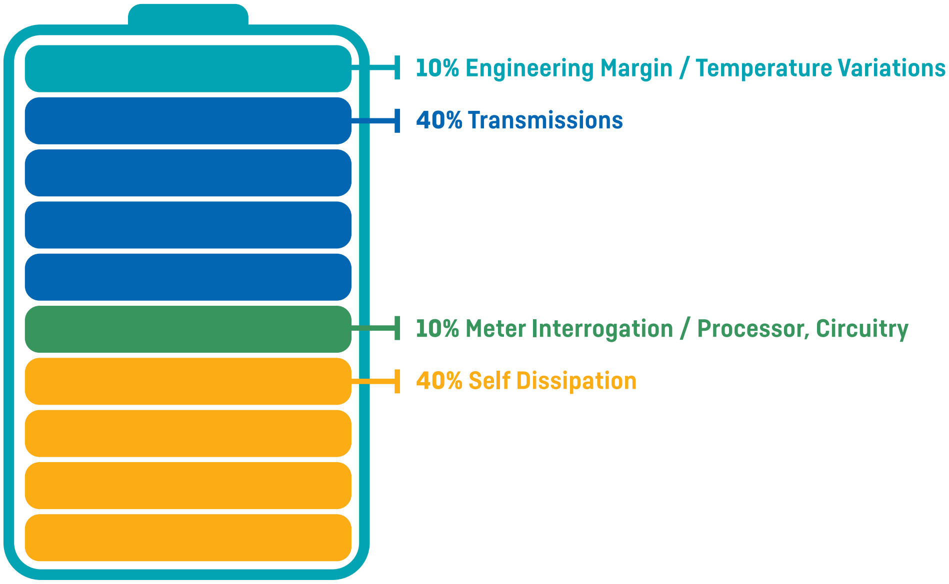
Figure 6 - Typically Cellular Handshake Diagram



Source: Sharma, Shree Krishna; Wang, Xianbin; 2018/08/08; "Towards Massive Machine Type Communications in Ultra-Dense Cellular IoT Networks: Current Issues and Machine Learning-Assisted Solutions."

To manage power, AMI devices must consider the following: the frequency and total airtime for uplink, downlink, and alarm transmissions, as well as the time spent listening for downlink transmissions. Additional factors include operating temperatures, connection retry attempts, circuit demands, safety margins, and the battery's self-dissipation over its useful life.

Figure 7 - Typical Battery Usage



Since “on” airtime consumes the most battery in most devices, the number of transmissions is crucial for the device’s lifespan and should be limited. Typically, this means the device will “call in” only a few times each day to conserve power, reduce the time and duration spent listening for downlink messages, and try to limit or manage alarm messages and updates.

To the utility, the limitations in transmissions affect the latency of the information available to the software. For instance, a Radio Frequency system may transmit every three to four hours and send alarm notifications within an hour of occurrence. This can be critically important for alarms such as reverse flow, high flow, and empty pipe. A cellular system may only report 1 to 4 times daily and retain alarm conditions for these transmissions. This reduces the system’s overall responsiveness and may undermine many desired operational efficiencies and customer service value propositions, such as high flow alerts to residents, water quality issues from empty pipes, or reverse flow.

This risk is further exacerbated when the unit attempts to reconnect to the collector. A retry may occur if the device fails to complete its intended transmission, leading to another handshake event. One of the primary causes of lost transmissions is interference from metal boxes, lids, and vaults. In areas where composite lids are not practical, this can significantly reduce and shorten battery life. Additionally, warmer climates present further risks as higher temperatures cause the battery to deplete more quickly, thus utilizing the engineering margin and potentially reducing the device’s lifespan.

In addition to managing communications, the device faces other challenges that prevent its useful life from reaching 20 years, including quality and battery longevity. These issues are not exclusively related to cellular technology, but cellular units are more vulnerable to risks associated with battery performance.

The hardware must be able to withstand 20 years of harsh environments, including temperature swings, UV exposure, corrosive soils, and submersion, to name a few. Historically, water intrusion has been the leading cause of product failure, resulting from water entering the device housing. Water can penetrate the housing through vulnerable areas, one of the most common being cable connections. This presents a challenging sealing task. Some manufacturers utilize potting, but this approach merely slows the water’s path and has historically caused other issues. The most impenetrable designs incorporate integral registers, eliminating the need for cable penetrations.

With a radio frequency-based AMI system, devices typically do not use the handshake, instead employing a broadcast methodology similar to that of a standard radio station. Messages are transmitted and received without needing to establish the same handshake between the device and the tower. This results in significantly lower power consumption for transmission. Additionally, devices can listen more frequently, making the system more responsive and informative. Examples include on-demand reads, immediate alarm transmissions instead of waiting for scheduled ones, responsive valve operation, and quicker over-the-air configurations and firmware updates throughout the device's lifespan.

Part 5 - Resilience – Is it what it seems?

Mobile Cell On Wheels

Lately, much hype has surrounded the recovery of cellular networks after natural disasters. The telcos have done a phenomenal job servicing their customers quickly after such events with portable equipment and personnel. One must wonder, shouldn't the measure of success be the system's overall reliability rather than just how fast it recovers after an issue? Inside of reliability comes robustness, redundancy, intelligence, and resilience. A utility should consider a holistic approach that includes all four facets. Generally, most radio towers are sturdy enough to withstand most storms. An additional measure for risk mitigation to avoid outages would be redundancy in coverage, which is challenging with some telco infrastructure. A utility or provider can also use intelligence to monitor issues, which can reduce outage exposure. If all of these fail and an outage occurs, resiliency becomes crucial. Utilities should ensure that resiliency measures typically deployed, such as mobile cells on wheels and other methods, effectively cover the bands used by the AMI network and not just mobile phone networks. Otherwise, the resiliency time may not be as swift as implied.

Part 6 - Conclusion

Despite the limitations of the cellular network, there are certainly some applications for which it is well suited. All networks are subject to coverage, capital costs, device lifespan, performance, security, network availability, and operational costs. In some cases, the costs to achieve coverage in specific areas may be high due to infrastructure needs, and utilizing existing networks may be feasible despite these limitations.

Additionally, devices with high data payloads, high latency tolerances, or the need for transmission confirmation are not typically expected to provide 20 years of service. Therefore, cellular or LPWAN technology may be a viable option. As the use of AMI networks expands, the foreseeable future will undoubtedly include a hybrid approach with networks that include radio frequency, cellular, LPWAN, and potentially other methodologies. Utilities are encouraged to review the applications and the total cost of ownership.

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