Ubiik's Advanced Metering Infrastructure (AMI) Technology

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This article introduces the main elements of Advanced Metering Infrastructure (AMI) for smart metering and monitoring of electricity grid power systems. Come and join us as we explore the basics of smart metering, wireless communication, data aggregation, backhaul and backend networks and their essential roles in providing high quality smart device solutions. We discuss, briefly, how Ubiik's technology provides not only AMI support to connect smart meters, but also how this technology can support a range of smart applications.

Transitioning from an old electricity infrastructure to a new one comes with a great many advantages. Among these is improved efficiency of operation, reduced costs, more targeted and proactive planning and maintenance operations, improved ability to integrate intermittent sources of power generation and more reliable and accurate billing for end customers. A key technology in this transition is the implementation of Advanced Metering Infrastructure (AMI).

Ubiik provides an efficient mechanism for the implementation of AMI at the national scales needed for electrical, gas and water utility management. For instance, in Taiwan, Ubiik's metering infrastructure is scheduled to operate across up to 280,000 electrical meters by the end of 2020. This infrastructure is done in support of the state-owned electricity grid operator, the Taiwan Power Company (TPC). Ubiik has won three consecutive contracts since 2018 for this work and consistently passed a series of stringent acceptance tests for each of these.

Ubiik's AMI technologies collectively allow for very high frequency measurements at intervals of 15 min or shorter at availabilities of 99%.

In order to support the Taiwan electricity grid, Ubiik has provided a full vertical solution consisting of implementations at the meter level all the way up to the cloud with Software as a Service (SaaS). Ubiik's role is that of a service provider for a Weightless Protocol based RF network that specializes in IoT and M2M applications.

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Technology Overview

Ubiik’s AMI infrastructure can be divided into five main logical parts as shown below and on the next page. These elements function together to provide a complete solution for AMI.

Smart (digital) meters

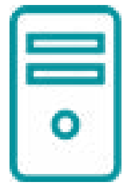
Smart (digital) meters at customer sites to make measurements of utility usage. For example, meter measurements of active, reactive power and energy usage can be collected for electricity meters.

Wireless control and transceiver board

Wireless control and transceiver board connected to each meter for transmitting usage data upstream for aggregation. In Taiwan, these devices are sometimes known as Field Area Network (FAN) devices for utility billing applications and as Home Area Network (HAN) devices for dual home and utility applications.

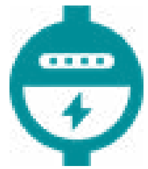
Data Concentrator Units (DCU) or Base Station (BS)

Data Concentrator Units (DCU) or Base Station (BS) to aggregate data from multiple FAN devices. The DCU acts as a hub and interface between FAN devices and a backend system.



Backhaul networks

Backhaul networks for transmission of aggregated data to a backend server. Here Ubiik’s **Base Station Controller (BSC)**—similar to a Network Manager or Core Network in other wireless network systems—combines with a **Head End System (HES)** and acts to provide backend communication management, application server and database system.



Meter Data Management Systems (MDMS)

Meter Data Management Systems (MDMS) that collects and validates data received from the HES for billing and that allows for further analytics by the utility provider or end business. Such a system can be substituted with a scaled down approach in industrial situations where billing requirements and external customers may not be the primary focus of a business. Separate from the MDMS, a **client-side front-end system**, along with webserver, provides a user interface (and/or APIs) for visualization, reporting and actionable analytics to users

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Architecture Overview

Figure 1 below demonstrates the different elements of Ubiik's vertical solution. This solution is centered around Ubiik's Weightless protocol to connect to a very large number of End Devices (up to 1000) per DCU (GUI frontend not shown).

Given the extent and scale of deployment in Taiwan, Ubiik carries significant expertise in implementing AMI solutions. Ubiik has national levels of deployment for its FAN devices, DCUs, Backhaul & HES backends as well as Client-side frontends. Smaller deployments using Ubiik's existing Weightless network have been extended to Gas and Water meters and other energy related management and billing services.

This article briefly outlines Ubiik's current and upcoming technologies for each of the main AMI components outlined earlier. This article attempts to demystify the technology and discuss, briefly, use cases in which Ubiik's solutions are most appropriate compared with other technical approaches for metering applications. There are merits of having a complete adaptable ecosystem that covers most AMI components to provide a Software as a Service (SaaS) approach. Such an approach aims to provide for the varying needs of industrial and government use cases. Let's take a look at each of the components in more detail.

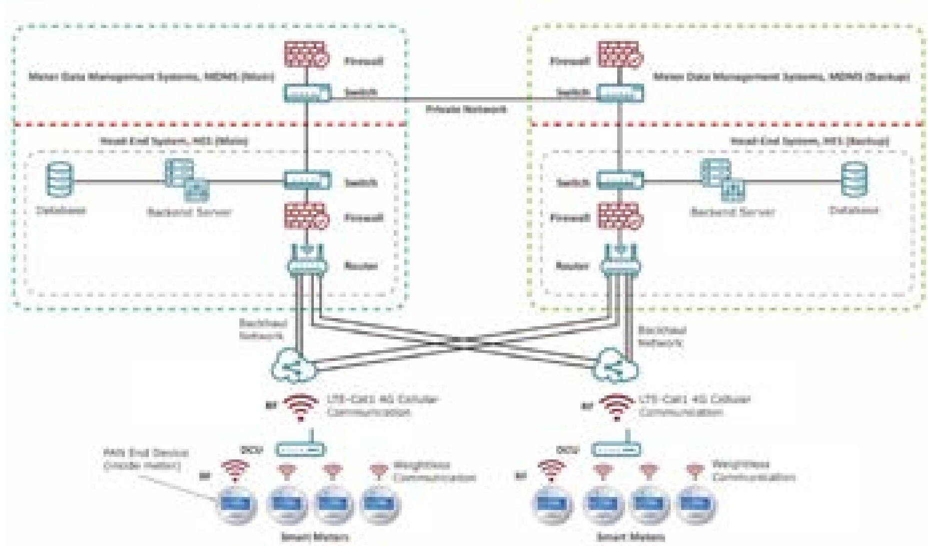

Figure 1: A general architecture of Ubiik's AMI infrastructure. Diagram sourced and modified from TPC [1]. This infrastructure consists of 5 main components starting from the FAN device (inside a smart meter) going up towards DCUs, a backhaul network, HES backend system, MDMS (and Frontend GUI). Note that in some cases, where device density is low, Ubiik FAN devices may communicate directly via cellular network.

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Smart Meter

A wide range of vendors are involved in the development of smart meters. **Figure 2** provides examples of some of these meters (from various vendors) into which Ubiik's technology has been integrated. The smart electricity meters in Taiwan follow IEC (European) standards, though the round shape of these meters is a typical feature of ANSI meters. In some cases, local CNS standards may also be used in Taiwan. From the perspective of Ubiik's work with TPC and the Taiwan Grid, successive AMI projects have been divided up into 3 segments: the meters themselves, the communication system, and the MDMS. Ubiik is a qualified vendor for communication systems and takes the role of integrating necessary wireless communication into the single and three phases meters deployed by TPC's chosen meter vendors.

Figure 2: Examples of some existing meters into which Ubiik's technology has been integrated.

Furthermore, this communication system is extended to upstream data transmission as well as back-end data management, analytics and front-end interfaces needed by Ubiik as a network operator and data service provider. In this way a SaaS solution is provided for these meter vendors, by Ubiik, thus offloading the burden and know-how required by these vendors towards meeting the full range of needs for their end customers

This integration can be supported further by meter vendors adhering to Device Language Message Specification (DLMS) and Companion Specification for Energy Metering (COSEM) standards – in practice this may not always be the case. This standard offers an interoperability layer that allows communication between a wide range of energy devices. This interoperability layer at different levels of abstraction can allow integration into existing solutions for specific vendors with relative ease.

In the international environment, some customers require a complete vertical solution for their needs. Ubiik's approach provides full vertical integration including the meter itself, where needed. For instance, Ubiik's recent work developing AC/DC electrical meters and gas meters provides a case study. Beyond metering, Ubiik's communication technology has also been integrated into other smart devices, for instance, e-Paper devices for displays applied to asset management and tracking tasks. A future article will discuss this work in more detail.

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Wireless Transceiver Devices or FAN End Devices

Getting data from meters in the field can prove a daunting task. In the case of utility level deployment this can mean the implementation of hundreds of thousands to millions of smart meters. Each of these field devices must reliably negotiate and transmit data at regular intervals or at demand from an upstream controller. And this transmission must occur under a wide range of varying environmental conditions. Of-course, devices are not limited to just smart meters. In-fact, when it comes to data transmission, Ubiik approaches the problem from a much wider angle of providing solutions that can meet the needs of a range of Internet of Things (IoT) devices rather than just applications in AMI.

Approaches for transmission can be either wired or wireless. In Taiwan, installation locations for meters often may not have access to physical wired communication lines without significant additional cost.

Ubiik provides a communication solution at national scales, which aims to save costs compared to other solutions. There is a bewildering array of choices for wireless data transmission. This range of choice can make it extremely difficult for customers or designers to select a good quality solution for their needs. The key in assessing the relevance of a solution is to look at a range of metrics and identify those most relevant to your application use case. For instance, **Table 1** demonstrates a range of criteria or metrics that might be relevant - note that the list is by no means exhaustive.

Criteria or Metric
A. Communication Range
B. Number of Devices
C. Bandwidth & Frequency Range
D. Scalability for Bandwidth Efficiency
E. Communication Security
F. Data Throughput
G. End to End Latency
H. Quqlity of Service (QoS)
I. Mobility of Devices
J. Deployment Cost
K. Topological Constraints
L. Extent of Deployment
M. Ease of Integration & Maintenance
N. Interoperability, Open Standards & Docs
O. Power Consumption

Table 1: Some (but not all) of the criteria for sifting through and selecting appropriate solutions for AMI & smart meter or IoT device communication..

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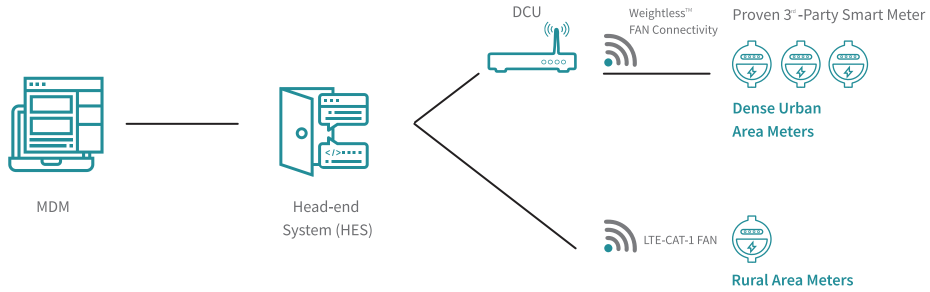
The use of standard cellular wireless technologies (e.g. 4G) does not always scale well to the many battery powered applications and lossy environments typical for many IoT devices. Ubiik’s wireless communication solutions focus primarily on the use of Weightless technologies to provide the bulk of Low Power Wide Area Network (LPWAN) communication needs with meters. It should be noted that Ubiik does support other technologies such as LTE-Cat-1 (for DCUs), NB-IoT and LTE-M, where use cases require, but these remain in the minority. Weightless has proven repeatedly to provide an optimal connectivity approach (relative to the criteria in **Table 1**) compared to other technologies for IoT connectivity solutions at national scales. A detailed discussion of LPWAN technologies by Rayal et al. [2] elaborates on this and provide an analysis of technologies such as WirelessHART, Weightless, Wi-SUN, Silver Springs (SS), LoRa, SigFox, Telensa, QOWISIO, NB-Fi, N-Wave, DASH-7, INGENU, NB-IoT/LTE-Cat-NB (Cellular), NB-LTE (Cellular), LTE-M/LTE-Cat-M (Cellular) and EC GSM-IoT (Cellular) [2,7]. Most technologies within the arena of LPWAN sacrifice on mobility, reliability, scalability or high data rates in favor of lower power consumption, stationary, and longer-range applications that can potentially support more smart devices.

This compromise isn’t always clear cut though. By way of example, SigFox and LoRa, may face increasing interference as number of IoT devices increase. Ubiik has likewise seen problems with decreasing reliability as number of devices increase in NB-IoT solutions as well.

Some companies have suspended or scaled down their NB-IoT AMI services in favor of LTE-M or LTE-Cat-1 as well [8].

It is in this context of challenging and lossy environments that Ubiik attempts to provide an optimal configuration with its FAN Weightless communication. To do this, Ubiik has developed an open standard for the Weightless Protocol [4]. Some examples of Ubiik’s implementation and integration of FAN devices into smart meters in Taiwan are shown in **Figure 3**. **Figure 4** also shows the FAN communication device itself.



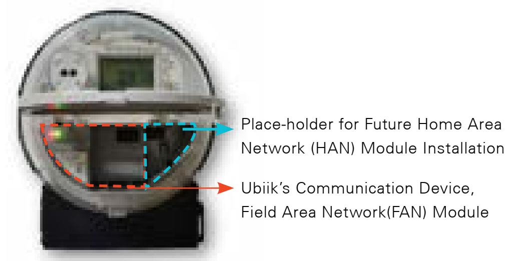


Figure 3: An example of how Ubiik’s FAN solution fits into existing smart meters. On the top is a demonstration of Ubiik’s LTE-Cat-1 and Weightless FAN connectivity architecture. On the bottom, the FAN installed in a meter. In Taiwan, future additional devices for higher frequency applications (e.g. HAN) can be added to smart meters.

Figure 4: Ubiik’s FAN communication device.

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This Weightless LPWAN approach aims to address smart applications that fit into the following scope and set of needs—refer to **Table 1** for the criteria associated with the letters shown in this list.

1. Mostly stationary smart devices with some roaming capability (I).
2. Low power operation with battery life in the range of years (O).
3. Long range transmission (up to 2 km city and 10 km in suburban areas) (A).
4. Secure (E), reliable and interference tolerant communication in lossy areas (H).
5. Support for large numbers of devices (up to 1000 devices per DCU) (B).
6. Low cost integration (J, M) with existing smart devices.
7. Deployment under varying regulatory and licensing environments (C, L).
8. Ease of integration (M) and accessibility to open documentation (N).
9. Low maintenance costs (M) supported by remote firmware upgrades.
10. Moderate adaptable rate bidirectional throughputs for monitoring or control (D, F).
11. Firmware-Over-The-Air (FOTA) features for easy maintenance and upgrades (M).
12. Applications tolerant of relaxed latency (G) constraints (10 - 100 milliseconds).

Where device densities (approximately 30 devices per DCU) may not be high enough to warrant the costs of a dedicated DCU base station, Ubiik LTE-Cat-1 and NB-IoT FAN devices may be deployed that utilize existing cellular networks to communicate with Ubiik's backend system. It should be noted that an End Device Module (EDM) is also available for integration into products for direct implementation of the Weightless protocol where necessary.

Data Concentrator Unit (DCU)

As seen from **Figure 1** earlier, a DCU acts as an intermediate data aggregator of FAN devices installed in smart meters. The relative cost of Ubiik's FAN device is amongst the cheapest (a few USD) of LPWAN solutions relative to the high quality of performance offered. The DCU reduces complexity at the FAN to achieve this cost to performance ratio. **Figure 5** shows some examples of Ubiik's DCU installations in Taiwan.

Ubiik's deployment of relatively few DCUs (around 320) can easily support about 280,000 FANs with significant capacity to spare. The cost of deployment of these DCUs, given the number of devices supported, only marginally adds to FAN cost and results in significant cost savings for vendors looking to integrate a wireless transceiver into their smart devices. With a shift to underground cabling for power lines, overhead pole mounting of DCUs is occasionally not possible. In such scenarios the range of DCUs can decrease. In these scenarios, Ubiik has under development specialized mini-DCUs (Janus devices) mounted at ground level and available at significantly lower costs than the pole mounted devices shown in **Figure 5**. These mini-DCUs aim to provide resilient long-range communication at optimal cost where other solutions may not work. Further, the DCU plays a central part in achieving power performance over other LPWAN solutions. Likewise, Ubiik's DCU acts to provide star (point-to-point) topologies for interconnection between DCU and FAN devices to reduce power loss resulting from multi-hop transmissions along mesh or tree networks (e.g. LoRa and Ingenu are examples of mesh networks).

DCU cell beacon channels (for FAN device discovery) and data channels are (see **Figure 6**) dynamically allocated. By sensing interference across channels Ubiik increases reliability of transmission (in potential conjunction with upstream backhaul and HES backend) and allows frequency hopping for data communication. This intelligent dynamic allocation can also make use of whitespace between channels to support lower interference during data transport. FAN devices are discovered through beacons generated by DCUs and a registration process ensures security and authentication.

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Figure 5: DCUs installed at three different locations in Taiwan. Ubiik provides 320 DCUs to provide communication that will provide service to roughly 280,000 FAN devices in Taiwan by the end of 2020. Middle location is a pole mounted DCU, while right location is mounted at ground level.

In remote areas where device density of FAN devices is low. The cost v.s. benefit to installing a DCU diminishes (i.e. less than 30 FAN devices per DCU). In such scenarios, Ubiik provides an LTE-Cat-1 FAN device approach which bypasses the DCU for direct data aggregation at the HES backend. Ubiik also can customize solutions to provide further support for other specific needs of individual customers.

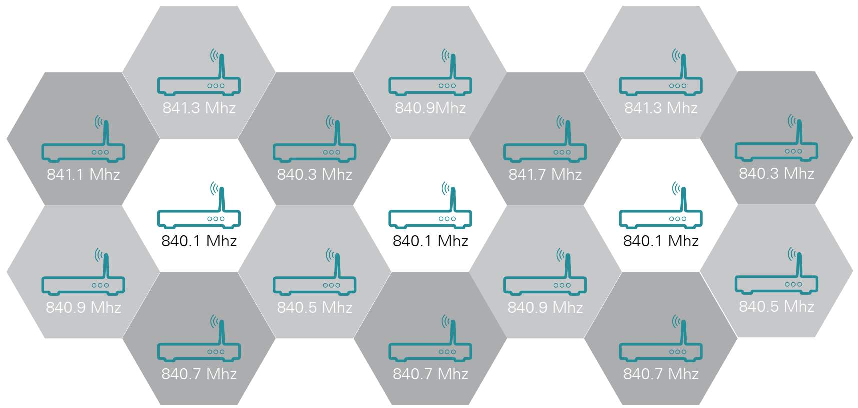

Figure 6: Ubiik DCUs are arranged in cells. DCU communication can hop between channels or into whitespace between channels to provide resilience against interference. Note that diagram does not capture details of this behaviour.

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Backhaul Networks & Head-End Systems

DCUs, LTE-Cat-1 & NB-IoT FAN devices interconnect with a backhaul ethernet or cellular network. Typically, the use of this network is negotiated by an existing telecom provider. In Taiwan, one such provider used by Ubiik is Chunghwa Telecom. A SIMM installed in either the DCU or the LTE-Cat-1 FAN has an associated monthly cost. The use of a single DCU aggregating data from a thousand devices offsets this cost significantly.

Figure 1 earlier in this article presented a simple view of the Backhaul Network and HES. Figure 7 provides a fine grain view of Ubiik's approach to managing downstream FANs and DCUs. The backhaul systems provide secure, AES128 encrypted communication with the HES side application servers. A Base Station Controller (BSC) provides a network management layer that creates an interoperability for interfacing with HES services. Ubiik's HES operates a series of portable and scalable microservices (e.g. Alarms, Security, Access Control, etc. as shown in the figure) utilizing common messaging buses to provide reliable processing and packaging of up-to-date and timely information for MDMS or client-side purposes.

For this upstream transmission, an API layer provides interoperability with XML, SOAP and other standard messaging formats. This high level of interoperability allows Ubiik's approach to be seamlessly integrated with products from other vendors at all levels. Redundant servers and database systems also securely store high resolution data at 15 min time intervals (or shorter) for long-term redundancy and reliability purposes.

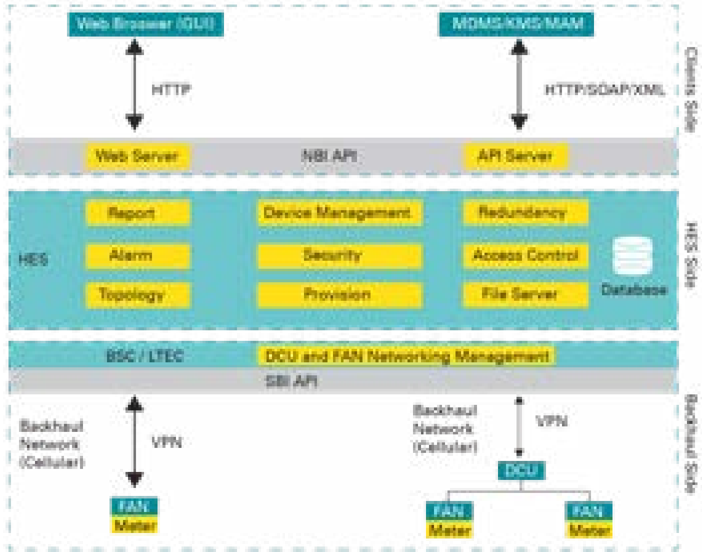

Figure 7: A closer look at Ubiik's backhaul, HES backend, MDMS and Client-side frontend approach. .

Meter Data Management (MDMS) & Client-Side Systems

While Ubiik is not yet a complete MDMS vendor, developments are rapidly under-way towards this goal with future projects providing support. At the same time, Ubiik can also provide front-end interfaces, APIs and underlying backend services for clients through the support of a SaaS solution. By way of example, the HES side tools deliver four main types of data to the client-side and MDMS side for electricity meter AMI. These include the following:

1. Midnight Register Data accumulated from all meters (delivered daily)
2. Meter Load profiles from across the entire network (delivered every 15 min)
3. Event data from meters across the net work (delivered as they occur)
4. Power quality related (ALT) data (delivered hourly)

For other utilities such as gas and water or for industrial users, the specific data delivered and frequency of delivery varies according to needs. Collectively, data are used by the MDMS for purposes of customer billing and for other more analytical purposes related to distribution and power system analysis, outage management, customer service, reporting, forecasting and more. HES API provides the data delivery tools to provide this information for upstream services to use. Additionally, Ubiik delivers a SaaS solution with client-side interfaces to better visualize and manage the downstream smart meter or smart device network. **Figure 8** demonstrates an example of some client-side GUIs that have been provided by Ubiik for network management purposes.

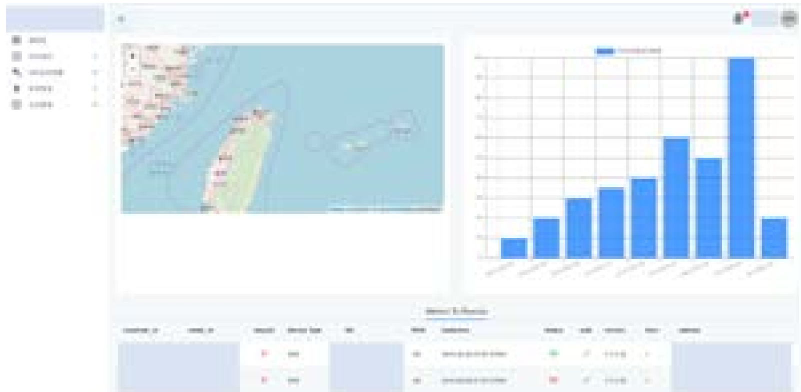

Figure 8: An example GUI for a client-side display. Note that purple areas contain confidential information and have been redacted

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Conclusion

There are five main components to Ubiik's solution for AMI. At each of these levels Ubiik provides a full vertical solution as well as one that can be integrated with existing technologies for not only smart metering but also for other smart applications.

Ubiik provides a flexible array of solutions for wireless interconnectivity via FAN communication end devices. These devices provide a mechanism for very large-scale deployment of Weightless with support from LTE-Cat-1, LTE-M and NB-IoT connectivity as needed.

The Weightless open standard also makes it easy to integrate Ubiik's technology into existing devices and networks by integrating an End Device Module (EDM) component to provide wireless connectivity on their Printed Circuit Board (PCB). Upstream of these modules are DCUs or Base Stations that aggregate and package data from FAN devices and intelligently manage communications to minimize power consumption while improving reliability of communication. Data from these devices are aggregated together and sent via a 4G (or ethernet) backhaul network to a HES backend. Here network management and data management infrastructure ensure reliable coordination and operation of the FAN-DCU communication network. A SaaS approach is provided by Ubiik so that clients can make use of the network and its data for monitoring and automation activities. Ubiik's MDMS will, in the future, provide functionality allowing further analytics and billing applications as well.

If you have a smart application you would like to consider, Ubiik will be happy to evaluate and help as best as we can. As a data service provider for IoT and M2M applications, Ubiik is ready to support your needs.

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