MOSAIC:
A Fresh Approach to AMR Networking
Part I

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This is the first in a series of whitepapers that explain distinctive design, function and applications of MOSAIC.

Part I deals with three "intelligent" aspects of the system:

- Self-Configuration and Discovery of Meter Interface Units within a MOSAIC Mesh Network
- Directionality within a MOSAIC Mesh Network
- Conservation Monitoring

MOSAIC Overview

MOSAIC is a mesh hybrid AMR/AMI system for collecting water, electric and gas metering data. It operates using walk-by, mobile (vehicle-based) and mesh network collection platforms. This paper focuses on aspects of the mesh network operations.

The system uses full two-way communications down to the endpoint, a FIREFLY® Meter Interface Unit (FF), making it possible for operators to "push" interval data requests, firmware updates, new capabilities and updated monitoring schedules out via the network. Radio communications use a Frequency Hopping Spread Spectrum (FHSS) schema within the unlicensed 902-928 ISM band.

MOSAIC is a MESH network. This means that all FFs also function as repeaters for the transmissions of other FFs around it. Data is transmitted – or "hopped" – from FF to FF toward a gateway, similar to the way someone might jump from rock to rock to cross a river. Transmissions follow any path necessary to efficiently navigate the network; circumventing temporary and permanent environmental obstacles along the way. Should the primary path be unavailable, the network "self-heals" and dynamically routes data via an alternate path.

By default, a MOSAIC network for water or gas meters "wakes up" and communicates for 6 seconds every 20 minutes, synchronizing all FF clocks and configuration information. Between these transmissions - called the "mesh duty cycle" – FFs remain in a low power state, conserving battery life. Water/gas MOSAIC networks report normal readings and alerts once daily.

Note: MOSAIC-class Electric FFs never enter the 20-minute low power state since they are connected to a power source. Electric FFs in a MOSAIC network communicate every 6 seconds and report reading and alert information every 15 minutes.

Water/Gas FFs log usage data hourly and store this consumption data for up to 240 days. This hourly consumption data is considered usage profile data or "ProfilePLUS". The ProfilePLUS data can be retrieved from any meter via the MOSAIC network or a handheld.

MOSAIC networks synchronize via an Internet Time Server and operate off of Greenwich Mean Time (GMT). A "Time Zone Offset" parameter exists for defining precisely when the units report their daily reading. For example, to make the FFs in the network send their daily read at 12am Central Time, the offset would be -6. To make them report at 2am Central Time, the offset would be set at -8. Thus, MOSAIC delivers precise snapshot of usage across the entire system each day, something not available with manual and mobile reading methods.

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The time that readings are received by the gateway are time-stamped as well. This allows for precise calculation of latency, shows performance throughout the network and provides the data necessary for optimization.

Self-Configuration and Discovery of Meter Interface Units within a MOSAIC Mesh Network

FFs are delivered in "ship" mode (dormant, inactive). Water/Gas FFs are activated by swiping a magnet on the side of the unit. Upon swiping, the FF comes out of ship mode and begins its self-configuration routine. Electric FFs activate after the meter into which they are physically installed is inserted into the meter socket.

The FIREFLY begins by automatically determining the type of register to which it is connected. This is done by sensing the physical wiring configuration. Water FFs can be wired for pulse, encoder or attached to direct read registers (via optic sensor FF). FFs can also be wired to function as dedicated repeaters.

Each FIREFLY FF contains the firmware necessary to connect to any meter supported under the MOSAIC platform. This eliminates the need for users to inventory multiple FFs models for systems with meters from multiple meter manufacturers.

Next, the FF enters a rapid search mode in order to compile a "neighbor table" of all other FFs, repeaters and Gateways within range.

The FF "negotiates" with neighbors to establish the FHHS frequencies it will use and the order in which it will use them.

The FF establishes which of the 24 communication timeslots available during each mesh duty cycle that it will use.

Mesh transmission frequency	Every 20 minutes (default, water/gas) Every 6 seconds (default, electric)
Mesh duty cycle	6 seconds
Maximum FF message duration	125 milliseconds
Communication timeslots per cycle	24 timeslots

The FF also receives a configuration message from the first neighbor with which it makes contact. From this neighbor, it receives the timestamp, firmware version and primary gateway to which it should be communicating. Time is synchronized and the firmware is updated if the version found on the network is newer than that currently on the FF. It is important to note that these updates can be received from neighboring FFs, they do not have to come from the gateway. This expedites the self-configuration and discovery process.

And unlike many networks, MOSAIC does not rely on routing tables nor does it require any kind of reinitialization to find new FFs as they are installed. FFs automatically join the network upon installation.

Once these operations have been completed, usually in less than one hour, the FF begins reading, monitoring and operating as a normal part of the MOSAIC mesh network.

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In summary, the self-configuration routine of the MOSAIC-class FIREFLY FF involves:

- Autodetection of the meter register type
- Rapid search mode
- Compilation of a neighbor table
- Timestamp synchronization
- Firmware verification and updating
- Primary gateway identification
- Commencement of normal operations

Directionality within a MOSAIC Mesh Network

One of the keys to MOSAIC's efficient network performance is that its communications are *directional* within the mesh. That is, FF transmissions move purposefully toward their primary MOSAIC Gateway, not indiscriminately throughout the network. MOSAIC's directionality conserves network bandwidth and increases efficiency by reducing the superfluous RF traffic.

MOSAIC-class FFs use a proprietary algorithm to derive a "routing metric". This metric is calculated using many data points and is evaluated each transmission. Three of the data points used to set this metric include:

- Number of hops required to reach the Gateway
- RF signal strength to neighboring nodes
- Type of FF

When a FF initiates a message, the data begins moving towards the Gateway. FF initiated messages follow a path of larger metrics toward lower metrics. Each message has the metric as an element and only FFs with lower metrics will pass the message on. This ensures that the data flows toward the Gateway. All transmissions are fully acknowledged.

When the Gateway initiates a message toward one or all FFs in the mesh, the routing metric is used in reverse. (Examples of this information: firmware updates, interval data request, programming changes, new conservation schedules). These messages travel from lower metrics to higher metrics. In addition, during each mesh period, the FFs synchronize their global settings. If I FF detects that it has older information than one of its neighbors, it will request that information from its neighbor automatically.

Conservation Monitoring

MOSAIC has a highly-configurable utility for monitoring water usage and compliance with conservation measures. It allows reasonable usage "rules" to be applied to each category of water customer.

MOSAIC allows utilities to define nine (9) different "zones". A zone is a user-defined weekly schedule that can be applied to a particular category of water customer. Examples of zones could be "West Side of Town", "Even-Numbered Residential Customer", "C&I", "Golf Course", "24-hour User", etc.

Each zone contains four (4) different daily templates that can be used in any combination to create a complete seven-day monitoring schedule.

Each daily template is composed of 24, one-hour monitoring periods, to which a usage threshold can be applied. If a customer exceeds one of these thresholds (e.g. watering on a restricted day), an alert is sent back to the office via the network.

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Schedules have effective/start and expiration/end dates and can be changed at any time.

FFs accommodate two (2) schedules: a current, operative schedule and a pending or queued schedule. For example, as a utility sees itself emerging from severe drought conditions, it may decide on 8/15 to ease watering restrictions effective 9/1. On 8/15, the utility can create and send a new schedule (with a 9/1 start date). The new schedule will propagate throughout the network and activate on 9/1.

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