Enabling Distributed Meter Data Management Using Mediation System

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***Abstract*—This paper proposes the use of mediation system as a light weight embedded software module in Distributed Meter Data Management (DMDM) platform in Utility domain. In DMDM platform, a head end system would collect the information from all the connected devices in a house/neighbourhood, perform meaningful processing and forward the processed information to centralized repository (or centralized MDM) system. Mediation as a module would be embedded in each head end system to perform distributed data management and send the limited yet useful information to centralized repository reducing the processing and storage requirement on the whole. Processed data by mediation system at head end system would also be available to the end customer(s) for real time updates rather than waiting for processing of data at centralized MDM in batch process.**

Keywords-Meter Data Management; Smart Grid; Data Management; Mediation system

I. INTRODUCTION

Utilities sector is undergoing a massive transformation driven by government regulation and commercial factors. Global leaders across the world have committed to reduce emissions significantly by 2020. EU targets to reduce the CO_2 footprint by 20% below 1990 level. United States targets to reduce CO_2 footprint by 17% below 2005 level. China targets to reduce the CO_2 level of GDP by 40 to 45 % from 2005 level. Smart grid deployments improve the efficiency within a utility's network, open up new revenue streams and provide enhanced customer services. Over the past few years, the rollout of large-scale smart meter deployments and the Automated Meter Infrastructure (AMI) that supports connectivity and bi-directional information flow has become the most promising and well proven domain to modernize.

Smart grid along with smart metering would play a leading role in achieving the defined targets. As per a leading research organization [2], global installation of smart meters will be more than 95 million in CY2013 primarily dominated by developed nations across North America and Europe. As per projected growth, there would be more than 450 million smart meters deployed across the globe in CY2018 primarily lead by Asia. Investment for smart grids would exceed $278 billion dominated by China, which accounted 22% of world's electricity production in CY2011 [3]. On an average, Compounded Annual Growth Rate (CAGR) for utility space is expected around 12-17% annually [2]. Also, going from one meter reading a month to smart meter readings every 15 minutes works out to 96 million reads per day for every million meters. The result is a 3,000-fold increase in data that can be overwhelming if not properly managed [6]. Telecom vendors, being established player in all communicating world, could play a pivotal role to further empower utility vendors with their existing expertize for effective and efficient deployments.

The transition to the smart grid is fundamentally driven by market forces. The smart grid's ability to make better use of existing assets, enhance reliability and minimize costly environmental impacts are all market forces that have substantial economic value for all the involved stakeholders like standardization bodies, government institutes, utility companies as well as end customer.

From end customer perspective, Smart Meter enables customers with greater control over their energy use and costs by allowing them to monitor their energy use online and determining which activities are contributing to their bills. Customers can online view projected monthly bills based on their current usage allowing action to be taken before prior to bill generation. Near real-time processing of this information can provide valuable insight e.g., smart meters that collect information; say every minute can help identify appliances that consume the maximum electricity.

Typically, Meter Data Management is centrally located where all the raw information from different smart meters are collected and saved for processing the information in the required format. This kind of centralized MDM solution leads to big requirement on storage as well as non-real-time update to end consumers.

In this paper, we discuss the use of mediation systems as a data management platform for Distributed Meter Data Management. Mediation systems allow events generated in asynchronous as well as synchronous fashion to be collected

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and processed. The events can be enriched and consolidated as per the requirement of ecosystem. Mediation system provides extensive capabilities for data management including DB support, archiving, complex data calculation, data analysis, auditing and version data management. Near real-time analysis and visualization of events can produce alerts and notifications that can be used as a feed back to end customer for real-time action.

To summarize, we will start by introducing Mediation system and elaborate on the importance of mediation system in telecom and IT domain. We then discuss the challenges posed for Meter data management due to ever growing data from smart meters and how traditional features of mediation including data management and respective processing capabilities could lead to efficient and effective deployment of scalable Distributed Meter Data Management in utility space.

II. MEDIATION SYSTEM

Traditionally, a mediation system collect data from the network, enrich that data via processing and then delivers the enriched data to the desired system as highlighted in Figure 1. Mediation system could be generalized as software component used for data transformation depending upon the business requirement.

Operators manage a large computing infrastructure comprising of a diverse set of hardware, software and applications. Mediation system plays a critical role in accurate and timely charging & billing of a variety of services including voice, data and multi-media services provided by an operator. These systems operate in a highly complex, multi-vendor environment and provide reliable operations, high performance and secure access in a data-intensive environment.

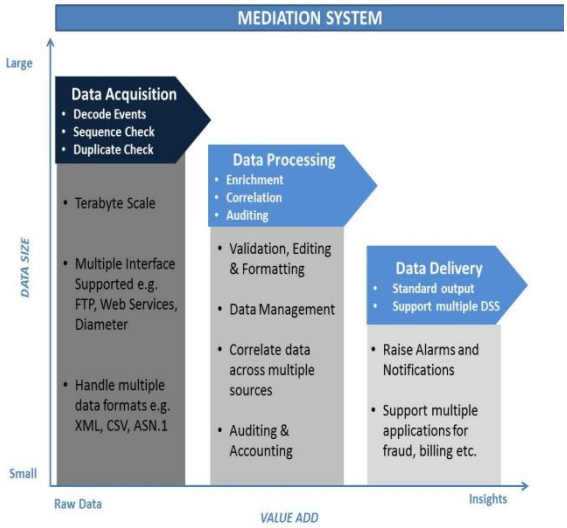

Figure 1. Overview of Mediation System.

Mediation systems collect data from multiple networks - 2G, 2.5G, 3G, IP, Fixed line. As part of basic processing, the events generated in different formats by different NE are decoded from XML, CSV, ASN.1, etc. to an internal data format for processing. Validation of event records is performed to ensure that they are received in the correct order [7].

Events can be enriched with information from external databases e.g., subscriber profile information can be added to the usage data. Event records originating from the same NE can be aggregated by the mediation system e.g., a long running call might generate partial CDR that can be aggregated to produce a single billable CDR. Event Records that are generated across NE can be correlated using a unique key (say, MSISDN, IMSI) to stitch together the multiple event records into one billable CDR [7].

Since billing can be based upon duration, volume, content value, time, Quality of Service (QoS) or a combination of these parameters, custom processing logic can be written to define these business rules. The logic also defines interfaces with external systems, error handling and configures notifications and alarms that can be raised.

Finally, the data records are encoded in a standardized format for downstream OSS/ BSS applications. Thus, these applications are completely abstracted from the multiple data formats, transmission protocols and receive standardized and complete records.

Near real-time and real-time mediation systems handle events in a continuous streaming format. Real-time systems can process information between 1 to 10 milliseconds whereas near real-time systems take up to a second for processing. As soon as events occur, usage data can immediately flow through the mediation system towards billing, network planning, fraud management and / or other OSS/ BSS systems.

Mediation system is software component which could easily be deployed, co-located with other telecommunication as well as IT based solutions on Commercial-off-the-shelf (COTS) hardware.

III. SMART GRID & DISTRIBUTED METER DATA MANAGEMENT

On high level, Smart Grid could be defined as convergence of IT, automation and communication technology in Energy Distribution Network. Smart grid is a modernized electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve

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the efficiency, reliability, economics and sustainability of the production and distribution of electricity.

Smart grids are intelligent energy networks which further add intelligence through new bi-directional communications and computer controls. There are many smart grid technology areas each consisting of sets of individual technologies that span the entire grid, from generation through transmission and distribution to various types of consumers like electricity, gas, etc. [9].

Meter data management (MDM) refers to a business process in the Smart Grid infrastructure primarily responsible for data management and VEE component as highlighted by Ericsson Smart Grid offering [4]. VEE component stands for Validation, Editing and Estimation modules.

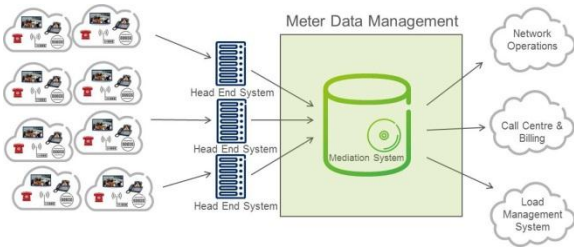

Figure 2. Deployment view for Meter Data Management.

As highlighted above, MDM is positioned between Head End systems collecting information from customer's premises and operator's backend system like Network operations, billing, load management system to name a few. In centralized MDM solution, all the raw information is collected at one centralized point and processed before forwarding it to respective backend system. This leads to extensive data flow among various nodes in MDM solution, support to handle BIG data as well as delayed update to the end customers including consumed unit, consumption pattern, etc.

MDM systems provide a database repository that automates and streamlines the complex process of collecting meter data from multiple collection points supported and deliver the data in an appropriate format to a utility billing system and other smart grid related applications.

As per IEC standard [1], the meter data management system is used to provide a common repository, and point of management and access of meter data that is collected from disparate metering systems. In addition to data aggregation, quite often the MDM will also make an effort to scrutinize the data collected from the various metering systems, and provide a validating, editing, and estimating (VEE) capability.

"VEE" means validation, estimating and editing of Meter Reads to identify and account for missed and inaccurate reads used to derive billing data.

Data Management & Repository is key component in MDM module. Data repository consist of saving raw data as well as processed data in required formats for long term storage as part of legal requirement. Stored data would be further analyzed in case of conflicts/complaints. This data should also be used for estimation purpose.

In real scenarios, more functions have been embedded in MDM module as highlighted in Figure 3. Various functions which are part of MDM solution offerings are Billing, Customer information, Revenue assurance and Auditing & Reporting, etc.

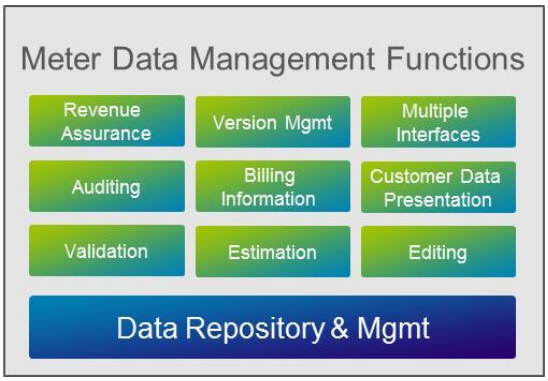

Figure 3. Functional breakdown of Meter Data Management (MDM) processes.

Billing customers is a critical process for a utility space and lot of resources, financial investment and time is invested since it is directly connected to revenue. Going forward, more efficient billing techniques would be implemented like Time of Use Billing, Critical peak pricing to reduce peak load and even out the load.

Auditing and Reporting process is an absolutely necessary module to manage and be in control of all the events performed in the system. Auditing should record all the modification, involving processed data like when, how and why an action was performed. End to End auditing for all the historical data and respective reporting framework are important aspects of MDM module.

One of the important advantages of Smart grid over traditional grid deployment is real-time meaningful update for the end consumers. MDM system interfaces with a number of different smart grid related applications supporting multiple interfaces.

Revenue assurance is the module that ensures a Utility Service Provider (USP) to accurately capture revenue for all services rendered. Possibility to track events through the business logic or to report events from within the processing flows are few of the mandatory requirements of the domain.

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In distributed MDM solution, primary responsibility of MDM module i.e. data repository and VEE component are migrated from centralized MDM platform to Head End system leading to win-win situation for all the stakeholders as highlighted in DMDM Patent [5].

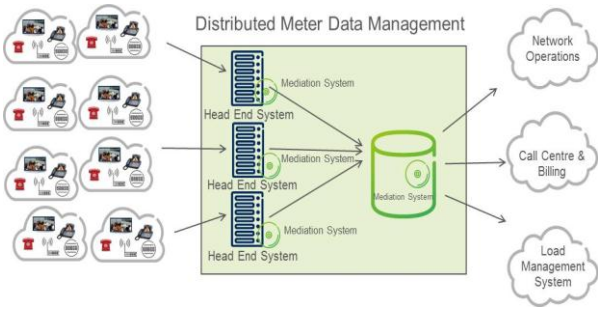

Figure 4. Deployment view for Distributed Meter Data Management.

IV. MEDIATION SYSTEM IN DISTRIBUTED METER DATA MANAGEMENT

As highlighted, Meter Data Management (MDM) refers to a business process in the Smart Grid infrastructure primarily responsible for data management and VEE component. Mediation system provides the inbuilt capability, and flexibility to realize the business requirements of Distributed Meter Data Management in scalable manner. In the below section, we will cover the two primary aspect of DMDM i.e. Data Acquisition and Delivery and Data Processing and how mediation system is a suitable fit for implementing DMDM module.

A. Data Acquisition and Delivery

Smart Grid Infrastructure is projected to expand rapidly, leading to complex network supporting new protocols, new technologies and new formats in real time.

As IEC recommends [1] , the system interfaces of a compliant utility inter-application infrastructure has been defined using Unified Modelling Language (UML). The Extensible Markup Language (XML) is a data format for structured document interchange particularly on the Internet. One of its primary uses is information exchange between different and potentially incompatible computer systems. XML is thus well-suited to the domain of system interfaces for distribution management. Meter Data Management module is supposed to interact with almost all the logical entity modules including, but not limited to, Metering system, Planning and Scheduling, Customer Information and billing, Work management, Network Operations and Load Management System.

Additionally, central to the customer benefit is the provision and presentation of data. Data can be presented in a number of different formats and on a number of different media (smartphone, web, customer bill, in-home display unit, and so on). Utilities with a commitment towards improving customers' visibility into their personal consumption behavior must ensure that Mediation system interfaces with a number of different applications supporting customer information.

Mediation systems provide additional applications and open API standards to integrate into customer management systems, Traffic management and network monitoring. Mediation also provides the support for flow based real time protocols which are extensively used in network monitoring domain and to build over the top applications as per customer specific needs like netFlow and related flow based proprietary protocols [7].

Mediation systems could be used as light weight Service-oriented architecture (SOA) application to communicate between multiple modules on different protocol like Web services, SOAP, FTP, and SFTP. Support for XML format is an integral part of the communication framework.

In MDM deployment, the requirement on communication interfaces would be same, if not more, to support different technologies and products available at customer premises in future.

As IEC suggests [1], MultiSpeak is also a distribution focused specification / standard that defines standardized interfaces among software applications commonly used by electric utilities. Also, it defines details of data that need to be exchanged between software applications in order to support different processes commonly applied at utilities. MultiSpeak recommends file based transfers and SOAP messages over HTTP, TCP/IP sockets.

There is no specification on transport level communication however flow of the information should be via standard data format, named XML, which is ubiquitously used in IT domain.

Web Services is widely used technique to send web request to support inter-operable machine-to-machine interaction over a network. It has an interface described in a machine-process able format (specifically Web Services Description Language WSDL). The basic Web Services platform is XML + HTTP and both these technologies are well supported by Mediation System.

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Additionally, Mediation system also supports wide variety of data formats like ASN.1/BER, Comma-Separated-Value (CSV), XML, MIXED format to name few [4].

To minimize the amount of data transmission between different logical entities in utility domain mediation system also support transferring of compressed data using various standard techniques like zip, gzip, pkzip, etc. This will overall reduce the load on the network however without compromising the quality of the processing

B. Data Processing

Data processing is key responsibility of Meter Data Management allowing operator specific business logic to be implemented in faster and reliable fashion. Data processing includes, but not limited to, Validation, Estimation, Editing, Auditing, Billing data management, Version data Management & Revenue Assurance functionality.

1) Validation, Estimation & Editing

Validation process consists of various checks to ensure the integrity of the received data. The mediation system checks meter readings for anomalies. Validation process could further be broken down on syntactic check, semantic check and business logic related checks. Mediation system can check the syntax of each data transfer that is received from an AMI. This can be expected to include checking that the data structure is consistent with the required standards in utility space and respective checksum calculations.

Mediation system can also verify the semantics of each data transferred that is received from an AMI. For efficiency (e.g. loading prioritization), the data in any one data transfer should be from the same meter and the data should also correlate with information in the respective header section.

Also, Mediation system should perform checks to ensure that all meters for which data is provided are currently active.

Once the data is received and validated by the Head end system, the raw information is stored in the Database module for further processing. Traditional use case of Mediation in IT domain is to perform Extract-Transform-Load (ETL) functionality which is used for data integration, data migration, and data analysis and data management. ETL is an essential component used to load the data into the data warehouses from different sources in multiple formats across different domains.

Each operator would need to define additional business logic as per specific utility operators need. Time gap check, Interval Data Management and missing Interval checks are three important issues encountered and are expected to be well handled by MDM system.

Mediations system also support Record sequence number check, Time Gap, Zero byte file check, Scheduled Collection and Post collection actions which are best fit feature for supporting VEE module.

Mediation system is capable of data estimation techniques when actual Meter Reads are not available in order to create estimated Meter Reads and Billing Quantities. The method of estimation shall be automated.

Mediation system accommodates the ability to apply customized estimation techniques for non-conforming commercial and industrial loads, or for groups of smart meters that require special rules, or that should not have estimation applied to them.

Estimation techniques could further be classified based on two different estimation techniques on

- Historical Data
- Linear Interpolation

Historical estimation routine calculates average daily load shapes using data from historical reference days. It derives interval-by-interval averages from valid intervals from the 3 nearest days of the same or like day of the week, accounting for holidays.

In the event the correction occurs at the very beginning of the data being validated, Linear Interpolation will attempt to find the last interval from the previous reading group in order to use it as the starting “anchor point” for the estimation. If there is no earlier reading group, Linear Interpolation will use the value from the first good interval for all corrected intervals typically less than two hours [8]. Similarly, in the event the correction occurs at the end of the data set, the routine will use the value from the last good interval for all corrected intervals.

Mediation system provides rich set of functions based on common language like Java where user could build the required business logic based on the specific required.

Additionally, Database interfaces are also supported to store the required information and perform the logical operations using procedures based on database. Relation Databases is supported by mediation systems primarily supporting JDBC based database like Oracle, PostGreSQL, etc.

Mediation system provides the editing capabilities of Meter data by both the MDM operator and authorized external users, though the mechanisms may vary. Viewing and editing of Meter data by the external entity will be restricted

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to respective owners and related meter ID numbers for which the external entity has been identified as primary authority.

2) Auditing, Version Management & Revenue Assurance

Auditing is defined as step-by-step record by which accounting data can be traced to their source. Every change made to the raw as well as processed information is tracked, along with who made the change, why they made it, and references to problems fixed, or enhancements introduced, by the change.

Auditing is an important, legal and operational requirement in the telecom and IT world. Mediation system provides detailed auditing capabilities with options to export the information to the external system for further analysis.

Versioned Data management provides the capability to provide the snapshot of the meter load at particular time interval in the past to resolve billing and legal disputes. Mediation system provides log records indicating which user or VEE process made changes to the data. For example, if a reading changes five times, the MDM creates five versions of that reading, each of which also has a reference time period, indicating when it was the current version.

Revenue assurance is a critical business process for utility industry since an efficient revenue assurance implementation could minimize the revenue leakage and maximize the revenue. Mediation system is integral part of revenue assurance function across OSS and BSS domain in Telecom. It provides inbuilt capabilities to store the selective information from the meter reads in the file or database, which could further be used for revenue assurance reports.

V. CONCLUSION

Driven by market forces including rising energy costs and technological advancements, Smart Grid along with Smart meters are poised to be an important revenue stream for Information and Communication Technology provider. This paper highlights the inherent advantages, in terms of features, that traditional mediation systems would provide for handling metering data from Smart meters in Distributed Meter Data Management solution.

Meter Data Management application is primarily responsible for data repository and management including Validation, Estimation and Editing. Mediation systems are already equipped to support centralized as well as distributed Meter Data Management.

In the future, distributed meter data management, enabled using mediation system, would play a pivotal role for Smart grid deployments across the globe.

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