Architecture and Data Flow Model for Consumer-Oriented Smart Meter Design

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1 Introduction

Modernisation of the grid is essential to address the drawbacks in the traditional system. The key requirements identified for Smart Grid are :

1. Accurately measure usage and identify leaks and thefts.
2. Identify the demand profile and provide measures to smooth the curves and thereby reduce the overall production cost.
3. Enable detection of power failure in real time and speed up the recovery service.
4. Provide quicker response to events and alerts.

1.1 Problem

Smart meter projects are facing considerable resistance from consumers. Consumers are concerned over smart meter but some concerns are perceptions rather than actual risks.

Table 1. Consumer Concerns over smart meter functionality

Smart Meter Functionality	Consumer Concerns	Consumer Values Affected
1. Collection, storage and disclosure of fine-grained consumption data	The data will provide insights into a household's living patterns to the extent that it could reveal sensitive information, including: 1. The appliances used in, and activities conducted by, the household. 2. Periods of absence of householders.	Confidentiality, Financial Asset Security, Personal Safety, Privacy
2. Data transmission and automated meter reading.	The data is susceptible to interception during transmission leading to modification or destruction of information.	Data Integrity, Availability of data, Availability of Power, Privacy, Security
	Exposures to radio frequency waves may give rise to electromagnetic hypersensitivity (EHS)	Health , Safety
3. TOU tariff to reduce peak demand.	Unable to avoid the peak period due to various reasons.	Comfort, Convenience, Cost
4. Remote switching (disablement and enablement) of supply	Possibility of being disconnected: 1. By error 2. By deliberate efforts by attackers	Safety , Security, Control
5. Enablement of energy export and calculation of net usage	Currently smart meter does not check before injecting the energy into the system and that could destabilise the system	Availability of power, Safety
6. Utility control over consumers' devices	Exercise of market and institutional power	Consumer sovereignty and self-determination

1.2 Proposed Solution

1. Identifying possibilities to reduce consumer concern about the data that is collected and accessed by organisations.
2. Consumer segmentation based on subjective control over smart meters.
3. A Smart Metering System Architecture with controls and choices for the consumer.
4. An abstract Data Flow Model that identifies the security and privacy requirement at each point in the flow.

2 Means of Addressing Consumer Concerns

2.1 Classifying data need for metering operation

Table 2. Options to reduce consumer concern over Smart Meter data

	Billing Operation	Demand Response operation
Purpose	Electricity is a service that needs to be paid for and hence the utility provider needs details of consumption to charge the consumer.	This data is required for identifying the rise and fall in demand in a locality.
Data Frequency	1. i) Less frequent and cyclic 2. ii) Intervals: Monthly / Quarterly / etc.	i) More Frequent ii) Intervals : 15 mins/ 30 mins / 1 hr /etc.
Effects on Consumer	Because of the low level of granularity, this data represents a very limited privacy threat, and has long been accepted as being a necessary element of the service.	This data is required frequently with or without a request. The transmission frequency can be programmed in the meter and back-end. This data could breach the security and privacy of the consumer.
Data Requirement	As this data has no other purpose apart from billing, it is only required on request from utility. Utility can send a request to fetch the billing data as per the billing cycle chosen.	Demand response data can be sent at intervals that are programmed at the meter or when triggered by requests sent from utility.
Options to reduce consumer concern		
Permission Control	i) Consumers exhibit limited concern about permission controls for this data. Billing data is the only method by which the consumption can be calculated and hence needs to be performed without any hindrance. ii) Consumers can be given the choice of billing intervals with a limit of one setting per billing cycle.	i) Consumer should be provided with choices on frequency of data storage, transmission and permissions to modify the energy usage. ii) There should also be options to disable transmission permanently or temporarily.
Storage settings	The data stored should be read-only. The data should be protected from unauthorized deletion and modification. This data should be available for billing verification in case of disputes	The data stored should be read-only. The data should be protected from unauthorized deletion and modification. This data should be available to other organisations only under strict controls. In particular, access for law enforcement purposes requires reasonable grounds for suspicion of relevance to the investigation of a criminal offence, and demonstrated legal authority.
Transmission settings	Billing should be calculated in the meter based on the TOU tariff declared. This eliminates the need to send detailed data for billing purpose. The data that required can be reduced to : a) Final (Present) Meter Reading b) Details of consumption accumulated under each period e.g. peak, off-peak and shoulder. This can be used to verify the bill calculation. c) Bill amount.	End user details are not required for grid operations, hence this data transmitted should be anonymous (when data leaves the smart meter) and aggregated (at the collector) to protect the privacy of the consumer.

2.2 Consumer Segments based on their reaction to Smart Meter

Table 3. Consumer Segments based on their reaction to Smart Meter

	User Characteristics	User Reaction
Type 1	They strongly object to the escape of personal data from their premises.	High resistance
Type 2	They don't mind having a communicating device installed but don't trust the meter functionality and they don't want any support and prefer to manage energy personally.	Low resistance
Type 3	They don't mind having a smart meter, but they want a very basic setting programmed into it, and do not want to make changes, preferably ever.	Neutral
Type 4	They would like to receive alerts and information through a smart meter but would personally make the changes.	Low acceptance
Type 5	Technology enthusiast and energy conscious user. They want to take maximum advantage of the functionalities provided, including programming the meter to switch particular appliances off during peak periods.	High acceptance

2.3 Consumer Oriented Smart Metering Architecture

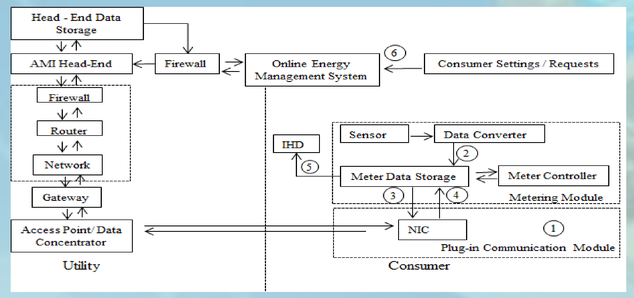

Figure 1: Consumer Oriented Smart Metering System Architecture

Table 4. Controls/Choices in the smart metering system architecture for different user types

Option	User Type	Remarks
1. Plug –in comms module	Type 1	1. If the communication module is of plug-in type, it can be removed for consumers that don't want a radiating device in their premises. Such meters have to be manually read and the utility may have to charge those consumers extra for labour cost. In future if they wish to use the data transmission functionality the communication module can be easily plugged in. 2. As there is no data transmitted to the head- end, details like outage and issues in QoS have to be communicated manually by the consumer. 3. Limitations - Consumers who worry about RF emission health issues may still be affected by radiations from neighbouring consumer's meter or collectors in the locality.
2. Choice in the interval of LP data storage	Type 1	As Type 1 user will not have a communication module, there is no requirement for them to store load profile data. Hence for such consumers there should be options to disable load profile channels and record no data. There could also be options for larger interval if required (e.g. 15 days / 1 month)
	Type 2	As Type 2 user will personally manage their energy consumption, they won't require frequent interval data. There should be option to program such users to larger intervals (e.g. 1 hr /2hr) just enough to supply information for grid operations.
	Type 3 Type 4 Type 5	These users favour frequent data collection and hence there should be 2or 3 options in the choices of shorter intervals (10 min /15 mins/30 mins)
3. Frequency of data transmission	Type 2 Type 3 Type 4	There should be options to : 1. Choose the interval of data transmission. It can be different from the interval in which data is stored. 2. Disable data transmission permanently or temporarily. Though the data can be anonymised and later aggregated during transmission there should be choice provided to disable data transmission. This will ease the worries of the consumer who think their energy consumption data could be used to profile them and distinguish if their premises are occupied or not. 3. Modifications to the data transmission should be notified to the head-end, so that they can use prior knowledge or other intelligence to calculate demand response. 4. Alerts like power outage and variations to QOS from the set thresholds don't affect consumer choices and hence that information should be transmitted to the back end without any interference.
4. Meter actions/ alerts/ Energy usage variations	Type 2	These users prefer not to use any help for their energy management, they only require options to receive alerts. Those alerts can be made available through In-House-Display or Online Energy Management system.
	Type 3	These users prefer not to constantly change their settings. Such consumers can be given the option to have the smart meter modify their energy usage during peak period declaration. If they have equipments with high energy requirement, that are not urgent they could be connected to the LC relay and made to switch off or cycle as per need.
	Type 4	These users prefer to be provided with alerts but wants the freedom to make choice of their energy usage.
5. Displaying usage with IHD	Type 1 Type 2 Type 3 Type 4 Type 5	All users, including the Type 1 user can utilise an IHD display to monitor consumption and other metering data at real-time, but Type 1 users won't be able to display alerts from the utility as they don't have a communication module. The smart meter should have a customisable display list for data to appear in IHD and there should be options to program the meter display based on consumer preference.
6. Setting Profile using online management system	Type 4	As these users would prefer to make changes personally, they can be given option through Online Energy Management system to make changes to the LC relay settings. Any equipment that is connected to the LC relay will then perform as per their chosen settings.
	Type 5	Technology enthusiast and energy conscious user who would like to make frequent changes to their profile settings can be provided with advanced options in online management systems for submitting their requirements. These requests should be first send to the Head-End and upon approval applied to the smart meter profile.

2.4 Abstract Data Flow Model for Smart Metering System

Table 5. Categories of data stored in the Smart Meter

Meter Data Type	Data Functionality
Detailed Data	This includes load profile data that is recorded at frequent intervals .This information is used for demand response and related operations
Accumulated Data	This includes accumulated consumption data which is not required frequently and in most cases, needs to be only sent when requested by utility. E.g. Billing operations.
Meter Profile Data	This data contains setting to which the meter should operate. Most smart meters have a load control (LC) relay and they can be made to operate differently from the main load by settings in the meter profile. Settings can also be provided to override operations commands from the utility.
Command Data	This data includes command and control operations received from utility. This data along with meter profile setting controls meter operations.
Display Data	This includes data that be programmed to be displayed in the meter's display unit and in other devices like IHD.

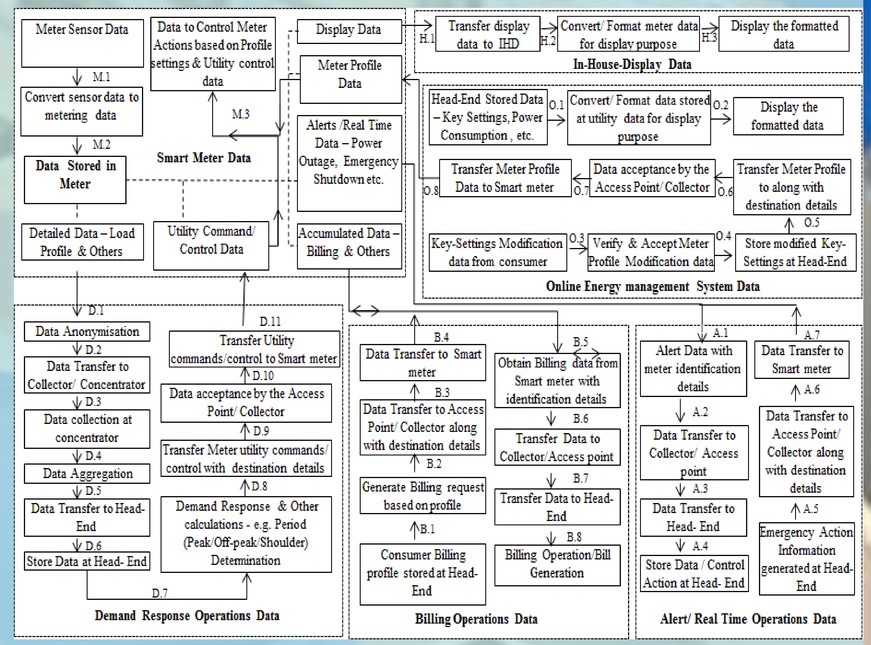

Figure 2: Abstract Data Flow Model for Smart Metering System

Table 6. General Security and Privacy requirements for Meter Data

These requirements should be applied as necessary at each point of flow of meter data	
G.1	There should be measures to ensure accuracy in data conversions and calculations. The integrity and authenticity of the data should be assured.
G.2	During data transfer, there should be measures to prevent loss and corruption. There should be measures to prevent interception and tampering. The integrity, authenticity and confidentiality of the data should be assured.
G.3	At various stages metering data will require formatting. Correct profiles and settings have to be chosen for each formatting to provide meaningful information. The integrity and utility of data should be assured.
G.4	During data storage there should be measures to prevent loss and corruption. There should be measures to ensure the storage is tamper proof. The integrity, authenticity, confidentiality utility of data should be assured.

3 Conclusion

1.Smart metering projects are at risk of consumer rejection, and investment failure.
2.We have identified ways to reduce consumer's privacy and choice concerns about data that is extracted and transmitted from a smart meter.
3.We have proposed a Smart Metering System Architecture and abstract data flow model that identifies security and privacy requirements to ensure consumer security and privacy.
4.New projects can adopt the design; existing projects can adapt their designs towards this model; this will reduce project risk, increase adoption, improve return on investment, and even salvage some projects from impending disaster.

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