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Fog Computing Application for Smart IOT Devices in Agile Business Enterprises

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Abstract

In the era of ICT revolution, the ubiquitous deployment of various kind of smart devices will require exploration of Internet of Things (IoT) to provide solutions with intelligent capabilities that fits our daily needs. In order to improve efficiency with reduction in data-load, processing and analysis becomes pertinent before storing it in cloud. However, processing big data in cloud will get costly and supporting layer in form of fogging needs to be introduced in between cloud and device applications. Fogging, better known as 'fog computing' creates a smart ecosystem for data processing in smart device or on the edge of the network. Sometimes, fogging is activated with other gateway devices thus acting as an intelligent layer between sensor nodes and cloud. Such approach has gained momentum, unleashing its scope in automation for diverse service sectors such as automobile, healthcare, financial services, reality, power and energy. This article reviews fog computing based IoT solutions and analyses the challenges to achieve enhanced system's intelligence, interoperability, energy efficiency, mobility, performance, security and reliability.

Keywords: Big Data Analytics, Bitcoin, Block Chain Technology, Fog Computing, IoT, Smart City, Soft Computing Value Chain

Introduction

We are in the age of digitization where internet of things (IoT) has dramatically supported business to undertake informed decisions in a secured and private environment to mitigate risks. Joseph and Kar (2017) has explained IoT as a network of tangible objects/devices with sensors, software that supports the collection, storage and exchange of data or objects via the internet or wireless. IoT devices perform as a micro-electromechanical communication systems without human to human or human to computer or machine (HMI) dependency (Chowdary and Muthineni, 2012). Growing numbers of networked, automated devices or sensors, and data processing devices are getting cheaper day by day as IoT supports soft computation to process and analyse data in real time scenario. Communication actuating system in a distributed network will be the next Future Internet (FI). The changing paradigm of static web pages (www) to social networking web (web2) and finally to ubiquitous computing web (web3) led to proliferation of smart devices in a

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communicating actuating network. Wireless technologies such as RFID tags, Sigfox a Low Power Wan (LPWN) and Zigbee (Mesh technologies) are likely to drive IOT research, transforming Internet into a fully integrated FI. In organizational context for applying innovation management (Malaviya, and Wadhwa, 2005) for achieving flexibility of systems (Gorod and Gandhi, 2008), Lepmets and Mesquida (2014) have proposed to evaluate innovation based IT service quality measurement framework.

FI comprising of IoT, IoS (Internet of Services) and IoP (Internet of People), can be regarded as a classic example of innovation management anchored on e-strategy model for creating flexible organization (Sharma and Gupta, 2004). IoS is a standardized enablers facilitating harmonization of various applications into interoperable services that employs semantics to comprehend and combine processing of information from different service providers. IoP on the other hand, involves people participating in ubiquitous intelligent networks, exchanging information in social context or environment. To meet the need of real-time analytics that delve into anything related to content specific information intelligence can be coined as Internet of Everything (IoE). Integration of IoE into cloud will not be a prudent decision to transmit all data into a bundle of sensor that reduces the performance capabilities of the system.

Gromoff and Kazantsev (2012) have proposed “newer approach to create flexible business architecture of modern enterprise” that can be further supported with information systems flexibility (Palanisamy and Foshay (2013). Fogging is an extension of cloud that increases the efficiency of smart devices with enhanced security and compliance. This in turn minimizes distance to data source and has its roots in meteorology where fog is a type of cloud that is observed closer to the ground. The term “Fog Computing” was introduced by the Cisco Systems which is anchored to edge computing concepts that enables new model to ease wireless data transfer to distributed devices (Choo and Chen, 2018). As cloud is unable to meet low latency, context awareness, mobility support requirements, IoT based machine to machine (M2M) devices on fog platform has been proposed. Fog controllers seamlessly blend sensors with actuators to evolve smart devices, transforming our modern day living dramatically.

Computing nodes have different architecture for cloud, fog and mist based applications. The cloud based computing is a global knowledge platform where the sensor data is communicated to a central server for analysis. But high bandwidth consumption and longer delays are the practical challenges for a cloud based platform (Stieninger and Nedbal, 2014). Conversely, fog computing is performed at the gateway devices, more precerisely at the edge of the network, reducing bandwidth requirements, latency, and the need for communicating data to the servers. The distributed and localizing architecture of fog nodes support IoT based M2M applications such as connected-vehicles, smart-grids, wireless sensor and actuator based networks where data acquisition by the devices occurs at the edges while its interpretation occurs in the gateway. However, the network delay and inefficient bandwidth utilization are limitations noted in fogging. Mist computing is the highest shift towards to the network edge, centred on the sensor closely connecting the actuator devices. This decreases latency and increases subsystems’ agile computation and actuation. The challenges of mist computing is complexity between interacting networks and device controls at individual level as central management of sub-system is not feasible.

Key Attributes of Fog Computing

There are some notable features of fog platform such as (i) heterogeneity, (ii) edge efficiency, (iii) geographical distribution, (iv) large-scale networks or nodes, (v) support for mobility, (vi) real-time interactions, and interoperability (Choo and Chen, 2018). Each parameter has been explained below with examples:

(i) Heterogeneity implies that fog is a non-trivial extension of cloud as it is exclusively located at the edge of the network and provides solution against limitations experienced in cloud computing.

(ii) The fog for its edge network, applications are manifold for example augmented reality, video streaming, gaming etc. because of its location awareness and low latency.

(iii) Unlike cloud, where services are largely centralized, fogging features flexibility to meet the demand of widely distributed deployments for example improved streaming to moving vehicles through proxies and access points along tracks and highways are positioned.

(iv) One of the examples of large-scale sensor network feature of fogging is in monitoring environment with smart-metering and automation embed into the system. Moreover, large number of nodes are employed/ interoperable for fog computing in particular for smart grid, connected public lighting which works on principle of distributed computing and big data storage resources. However, Bharathi (2017) argued that the security risks for big data information exchange cannot be mitigated easily.

(v) Predominance of wireless access, support for mobile devices (such as LISP techniques) decouple host identity from location identity is another important feature for fog application.

(vi) M2M real time interactions controlled through fog networks employ real-time interactions rather than localized, traditional batch processing with usual lag time. Since services (such as streaming) involves interoperability of fog components so that such services are federated across domains. These fast growing applications make fog computing as the most envisaged platform for IoT applications.

Hence, the fog, an intermediate computing layer between cloud and end device, is an essential paradigm shift towards hierarchical system architecture towards a more responsive based IoT architecture as shown in Figure 1.

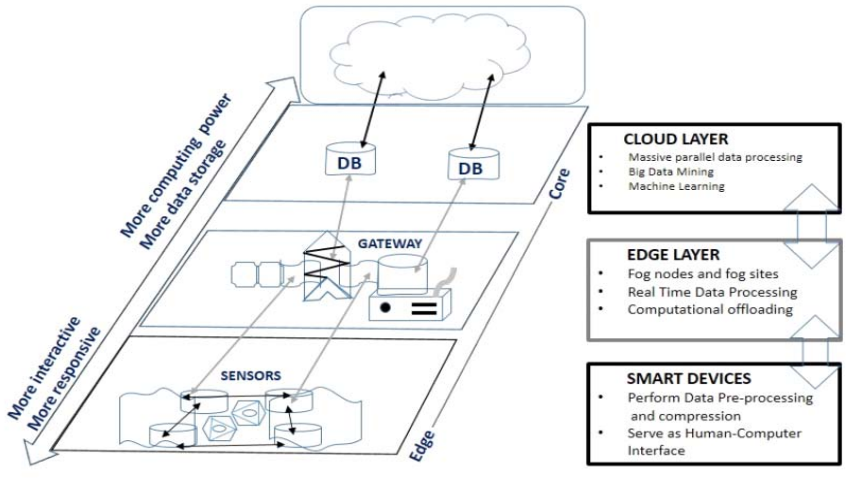

Figure 1: Functional Constituent of Fog Based IoT Architecture

The layers of fog computing with its functions are described summarily:

Fog Abstraction Layer

The fog abstraction layer performs following functions:

(i) Uniform and programmable interface for management and controlling physical resources such as memory, network and energy hiding platform heterogeneity

(ii) Acts as generic API to manage hypervisor, OSes, service sub-stations on a physical machine

Fog Service Orchestration Layer

The fog service orchestration layer is a dynamic policy based life – cycle management component of fog services. It is a middleware working on a large volume of fog nodes that is comprised of a software agent and a scalable messaging bus, distributed across wide geographical regions:

(i) A software agent with small footprint and capable of bearing orchestration functionality, embed in various egde devices, is known as foglet, functioning as a distributed policy engine with a single global view and local environment storing policies.

(ii) Scalable messaging bus to carry control messages for service orchestration that manages meta-data (capability, performance, etc.) resources, supports high transaction rate with updation and retrieval features.

Fog Computing Applications

Fog collectors present at the edge incorporate data from grid sensors and devices enabled with protect and control loops to conduct real-time processing (milli-seconds to micro-seconds). Fog in its first tier establishes machine to machine (M2M) interactions that collects, process data, filters and issues control commands to actuators. Then it sends remaining data to higher tiers may be at cloud level where visualization and reporting HMI systems display key performance indicators. Fog application stores data at ephemeral level in the lowest tier to semi-permanent level at highest tier with wider geographical coverage and longer functional time scale. Fog ecosystem performs seconds to minutes (real-time analytics), and even days (transactional analytics), supporting different time scale interactions at the data processing level. The localization provided by fog nodes together with global centralization in cloud acts as a repository for data storage permanently. Hence, data gets stored for months and years. Such combination of fog and cloud supports big data analytics where map and reduce exploits pig and hive tools in a hadoop ecosystem (Prasad and Vivekanandan 2015). Business architecture based on open source scala in spark is key resource for big data analytics in a modern and agile enterprise (Grover and Kar 2017).

Blockchain Technology and Bitcoin

Blockchain technology (BTC) is one of the upcoming areas of computing that can meet the challenges of current IoT applications and can mitigate risk of device spoofing and impersonation. Application of BTC concepts in shipping industry to circumvent manual process involves shipping company, port authorities and ground transportation systems to generate smart contracts. These risk -averse contracts leads to timely delivery of goods, anchoring to fog computation approach that enables real-time visibility and control over trade logistics. Block chain can be assumed to consist of a series of blocks connected in a hash chain, representing cryptographically secured shared ledger. This ledger is decentralized and gets updated with every transaction looping all stakeholders. Thus, it allows all stakeholders to have the same validated record of transaction, providing common ledger for letter of credit thereby attaining high speed of execution. Block chain enables secure mesh networks, creating ordered record of transactions which can be verified and easily replicable, public and removing intermediaries' / bank's approval. Blockchain distributed ledger technology provides improved medical record management, enhanced insurance claim process, accelerated biomedical research, and advanced biomedical/health care faster decisions which was referred as ‘Modelchain’ by Kuo *et al*. (2017) as it was guided by machine learning parameters to detect malicious attack from members / non-members.

One of the most popular applications of block chain technology is bitcoin, an emerging digital currency. Huang *et al*. (2018) have explained the bitcoin-based payments capabilities by activating the fog devices. Bitcoin is a crypto-currency in blockchain ecosystem where ‘blockname denotes a technique for decentralized resolution of endpoint address in an electronic communication system. Again, ‘blocklet’ denotes an electronic accounting system that builds upon the blockchain to provide autonomous, decentralized equivalents of traditional methods for commercial transactions, including contracts, agreements, receipts, and escrow arrangements. Bitcoin contracts involve transaction syntax in a secured multiparty timed commitment scheme. The fog user (outsourcer) with resource constrained device in this platform can outsource the distributed computation tasks to the unstructured fog nodes (workers) and pay for their completed tasks. Bitcoin’s steller has been trading at 4700$ in Aug’ 2017 though in Aug’ 2013 it was trading at 100$ only. This indicates within a span of four years, returns on bitcoin investments have sky-rocketed to 4600%, creating a history of most profitable investment of the world.

However, bitcoin network model consists of many untrusted nodes that routinely enter and exit the network. One of the challenges of bitcoin is privacy as transaction log is completely public. User’s privacy is only protected through pseudonyms and scope of money laundering by omitting legally binding financial reporting requirements cannot be ruled out. Another concern is that bitcoin transfers are irreversible. Even if the transaction is initiated by hackers trying to steal bitcoin, the transfer cannot be reversed. Once stolen, bitcoins are irrecoverable, making them prone to cyber- attacks (Roman *et al.*, 2018). Ionita and Patricu (2016) have devised mechanism so that fog computing finds way to strengthen cyber-defence to overcome security threats. Ionita and Patricu (2016) proposed for the first time to adopt micro-distributed Security, Incident and Event Management (SIEM)-like architecture that employs artificial intelligence to ensure safety in such irrevocable transaction networks. Artificial neural network has been programmed for collecting, analysing and sharing threat information. The fog architecture based on feed forward backward propagating neural network can measure risk calculated for different types of malwares and cyber-espionage. Soft computing has a pivotal role to play to safeguard BTC as cryptocurrency market has huge potential is safeguarded adequately.

Smart-Meter and Smart-Grid

IoT devices, powered by the wireless technology have transformed the electrical power industry by virtue of fog computation. It connects smart devices such as SCADA, smart-meter, building-automation, smart-grid, and connected public -lighting. Fog controller supports smart-grid infrastructure by increasing energy efficiency and storage. This balances energy consumption via smart energy-meter managed over Wi-Fi that helps to reduce operating costs by controlling metering operations remotely. Smart-meter improves forecasting capabilities and minimizes loss or pilferage of energy. Fog network at the edge consumes filtered data locally and remaining data is sent to higher tiers for real-time reports, transaction analytics and finally enables visualization to the utility companies.

Smart grids identifies areas lacking in power and surplus supplies by Ethernet based communication substations integrated with intelligent devices to optimize electricity generation and distribution depending on the demand and supply forecasts from real time data generations. Fog supports semi-permanent storage at the highest tier and momentary storage at the lowest tier. This mechanism eventually supports the generating stations to come online and fill the gap as the network edge processes the data collected by fog collectors and generates the control command to the actuators. With the use of smart-meters at individual customer location, the smart grid collects the current load data instead of historical data and then controls energy generation and load at each unit. This not only ensures the grid efficiency, but also takes care of the measurement and billing of the consumers. It can also be used for real-time identification of grid-faults accurately and restoration by studying fog signals.

Application of Machine Learning in RE Forecasting and Grid Stability

The historical data of a network can help the utilities forecast the demand of a geographical area using statistical modelling techniques such as ARIMA (Auto Regressive Integrated Moving Average) and SVM (Least Square Support Vector Machines). Especially for solar plants, the economic cost of interruptions can be significantly reduced to improve network reliability. Furthermore, Machine Learning (ML) techniques play a crucial role in decision-making steps regarding plant site selection and solar panel orientation depending on the solar irradiance of an area. Lastly to maintain grid stability, it is necessary to forecast both short and medium term demand for a power grid with renewable energy sources contributing in it. A forecasting model combining variable based algorithms like SVM can offer to manage the production and consumption in the smart grid and also efficiently process new energy measurements to detect changes in the upcoming energy production or consumption.

Fog Computation for Big Data Analytics in Smart Cities

Fog devices are having strong implications in smart cities to provide smart healthcare systems. Rahmani *et al*. (2018) have architected fog network based smart e-health gateway that activates IoT driven sensor on recording of anomalous health conditions of patients. Liu *et al*. (2018) have delineated flog-cloud interface requirement to develop a hybrid privacy preserving clinical decision support system.

A hierarchical distributed fogging for big data analytics in context to smart cities offer large-scale opportunities for businesses even in start-up phase to incubate technology and resources in intelligently programmed manner. This in turn develops urban centres that gets integrated, habitable and sustainable. Analogous to cloud function, fog leverages a policy-based orchestration and provisioning mechanism for scalable and automatic resource accurate function and management.

Fog architecture, based on its availability of heterogeneous nodes comprising of core, edge, access networks and endpoints or devices, facilitates seamless resource management across the diverse set of platforms. This shells into generic APIs such as Abstraction API, Orchestration API and Data API for application development and deployment in IoT devices. Fog networks experience the different hardware platforms with varying levels of RAM, secondary storage, and the platforms run various kinds of OSes, software applications. This results in a wide variety of hardware and software capabilities development ranging from high-speed links connecting enterprise data centres and the core to multiple wireless access technologies (ex: 3G/4G, LTE, Wi-Fi etc.) towards the edge. A Multi-tier (3/4 layer) fog computing architecture with abstraction and services orchestration layer can be explained in smart cities context which can be extended in smart home concept. Fog nodes are connected to IoT devices in smart city where smart vehicles are integrated with smart homes. A research onion based on fog controller applications in smart city as has been presented in Figure 2.

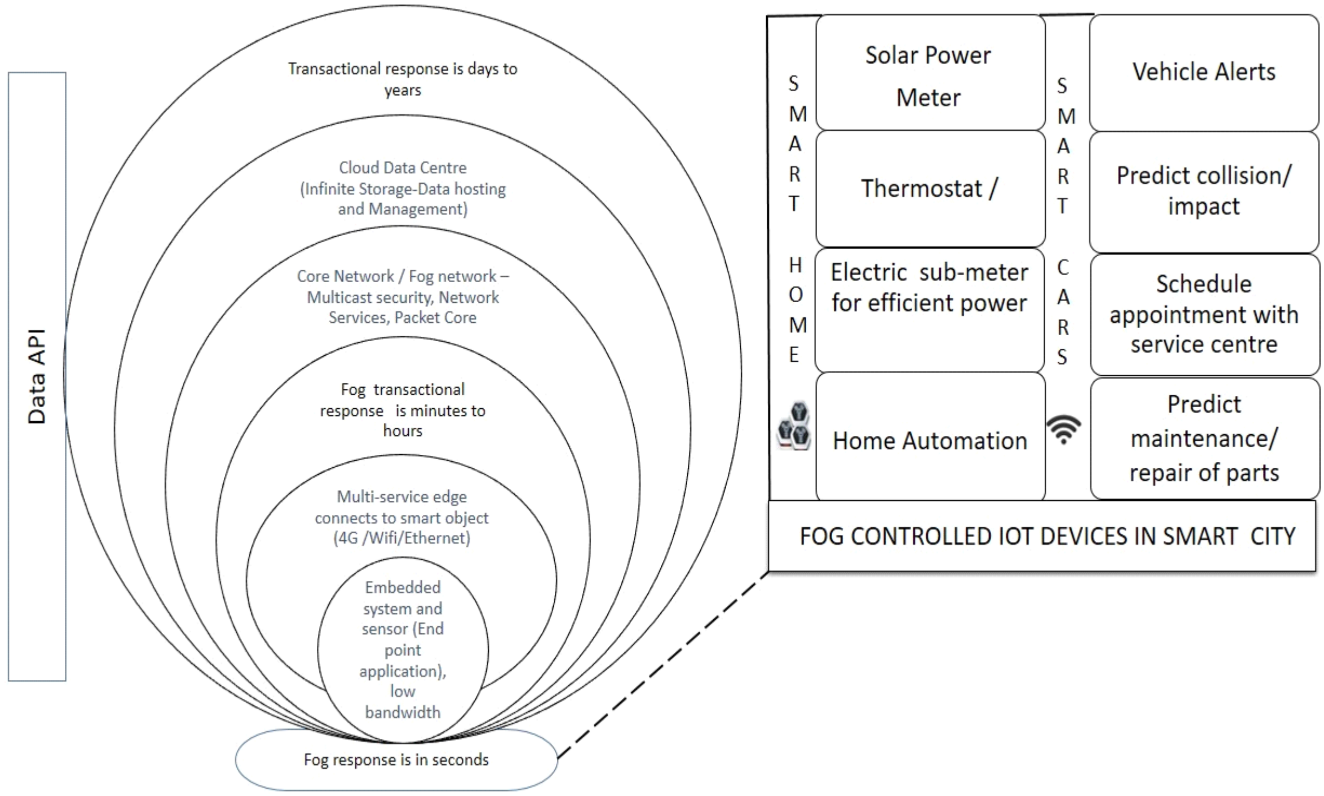

Figure 2: Research Onion in Fog Computation

Understanding of value chain in soft computing using fog controller is at high priority nowadays.

Holistic View of Soft Computing Value Chain

To increase the agility of business enterprise towards value proposition on product ideation, soft – computing approaches should be embraced. Gromoff and Kazantsev (2012) claimed that the several structure of the high valued optimized real-time business models are available. These business processes or services in the cloud can be made available to customers from the internet. Kryvinska and Hacker (2014) elucidates new product development (NPD) using social crowd integration concepts where cloud computing provided a safe and reliable soft computing embed business solution. As cloud computing is indispensable component of soft computing, Kar and Rakshit (2015) proposed a flexible pricing mechanism for Infrastructure as a Service (IaaS) in cloud. Here fuzzy set theory and analytic hierarchy process can be applied for decision making by multiple stakeholders in cloud IaaS. Identifying the value drivers using data mining concepts makes soft computing applications a costly software as a service (SAAS) product. Integrating the machine learning applications with the big data analytics offer flexibility in supply chain management. This apporah will enrich academic and industrial practises and employing big data tools (such as hadoop , scala, spark) on distributed network system can provide smart business solution (Grover and Kar 2017). Currently, the cloud platform for E-commerce is paving way for M-Commerce (mobile commerce), that features network flexibility, higher efficiency and scalability for improved users experience (Chhonker et. al 2017). The future of fog marketing lies in mobile edge computing (MEC), providing security of distributed computing, real time analytics and data management. Wang *et al*. (2018) conceived that fog nodes are composed of multiple mobile sinks that bridges gap between wireless sensor network (WSN) and the cloud to set up multi-input-multi-output (MIMO) network. Zhang et.al (2018) elucidated that fog nodes can measure uncertainty in communication for adoption of technology. Employing multivariate analysis –tools to offer flexibility in optimization of medical supply chain, Goswami *et al*. (2016) is in- line with the information exchange effectiveness concept in improving supply chain performance (Birasnav and Mittal 2015). Despite customer-centricity for cloud computing and wide adoption record in past, fogging with soft computing will be pivotal features in IOT devices. Application can be extended to Smart Traffic Light System (STLS) for smart connected vehicle (SCV) to prevent accident or build smart intelligent driverless-car where the local control loop subsystem can react within a few nanosecond to avoid accidents. Cloud based big data analytics for future cars in proposed smart cities after integration with fog computing can be broadly classified into three layers. The lowest layer of architecture is comprised of distributed and heterogeneous repositories as delineated by Khan *et al*. (2015) that can acquire clean and classified data. While the resource data mapping and linking layer (middle layer) can support the workflow and the natural query with an analytic engine. This supports the top layer processing for the distributed and heterogeneous repositories and various sensors that are subscribed to the system. Soft computing that comprises of statistics (Stat), ML and artificial intelligence (AI) is at the upstream of value chain while fog computing is arrested at the downstream of value chain. This can be represented below as shown in the infrastructure given below.

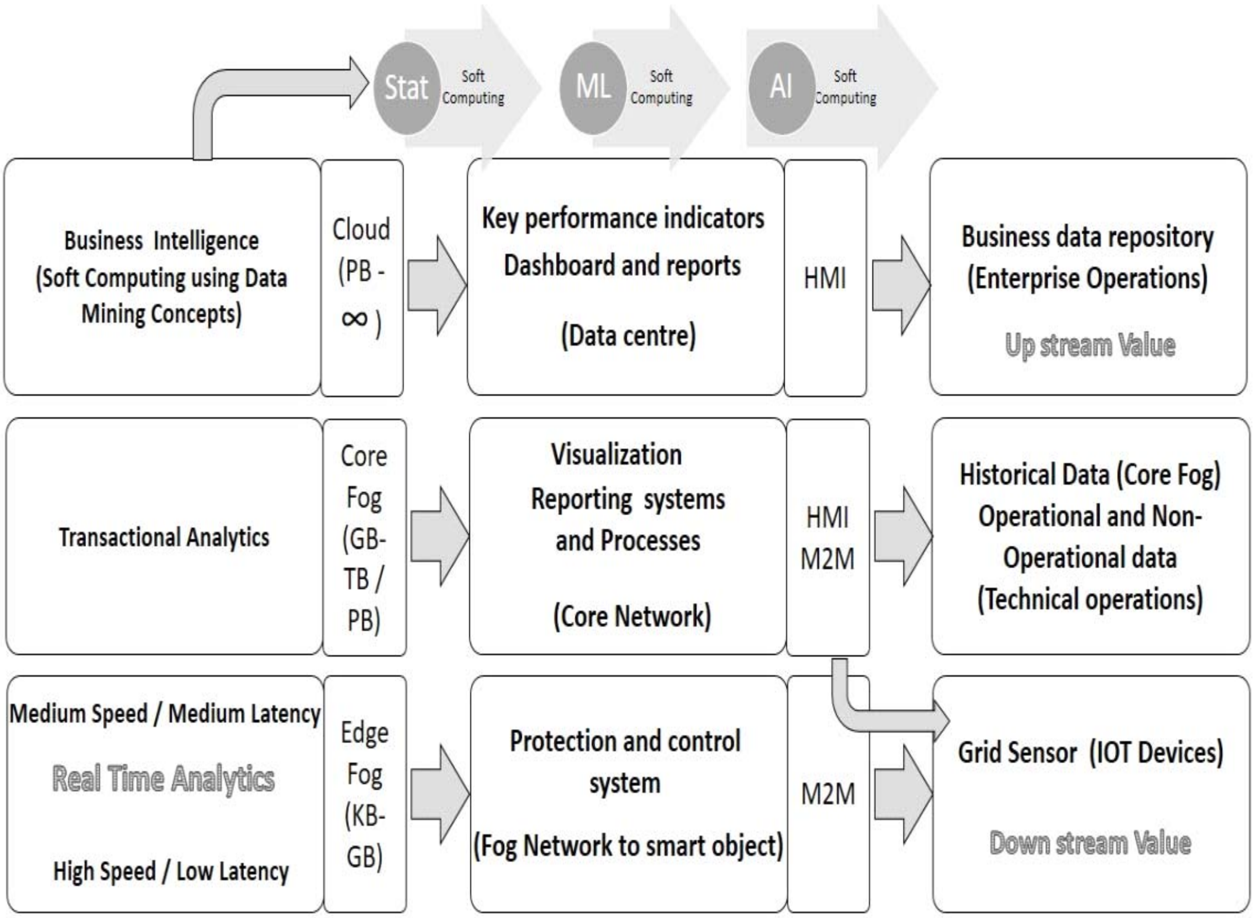

Figure 3: Value Chain Proposition for Stake-Holder's Adoption of HMI (Human to Machine) and M2M (Machine to Machine Interaction) Smart Devices Integrating Soft Computing with Fog Computing

Conclusion

Singh *et al*. (2013) highlights threat in internet security that IT firms operating on distributed network with multiple stakeholders coming into play. Both security and privacy are achieved in cloud computing but such solutions does not suit for devices that are at the edge of networks. Heavy computational tasks require large number of fog nodes. Hence, dividing tasks in blocks i.e. every node will be registered on the block chain that can support endless devices without need for additional resources. However, challenges on security and privacy needs to be addressed. Attribute based encryption for fog computing can be applied to cryptographic network that is expected to ensure the privacy of data computations. Yang *et al*. (2018) have elucidated position based key infrastructure to protect location privacy in the bounded retrieval model without incurring additional overhead cost. These authors further recommended using one-dimensional position relation for example location verification services in railway system, highway system and airline system. However, for three dimensional cases, limitation of this protocol is that it can only secure privacy if hackers are not at a half-line from the claimed region through a verifier.

Drawing analogy to Software Defined Networking (SDN) controller that updates flow tables in its flow compatible switches, which are usually closer to the client, the central authority of the fog computing performs in a similar manner. Here, the real-time load gets balanced and then ends commands to the fog controllers into geo-graphically distributed SDN networks. Fog controller, unlike cloud environment, supports storage of personal information in a set-top-box or a wireless access point. Fog offers smart network controls with networking device (router, switch access point), a set-top-box and an IP camera. These features essentially distribute videos and other video-on-demand content due to low latency, real time load balancing, geo-graphically distributed fail-over redundancy. Ionita, and Patricu (2016) security appliance and turned into a web proxy with filtering capabilities and a sensor for an upgraded Security Incident and Event Management (SIEM) system. Man-in-the-middle (MitM) attacks can be common in a geographically distributed network if correct cryptography has not been transacted.

In the realm of the prospective soft-computing integration with fog computation, a high value proposition for IT as well as non-IT industries, can be unleashed. The opportunities of industrial automation lies in fruitful exploitation of fog computing, an extended product of the cloud computing that anchors IoT based devices. Many applications based on fogging such as BTC, connected-vehicles, wireless- sensors with actuator networks, smart-gird, wind farms, smart-cities and health, can be the next level of the future of IoT devices. To conclude, the soft computing by joining cloud network with distributed fogging routes towards a wireless sensor, will create the much envisaged value proposition for the stakeholders of the IOT based supply chain.

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