FULLY CONNECTED TRAVELLING: A STEP TOWARDS SMART CITIES

[1] Urooj Yousuf Khan, [2] Muhammad Nawaz Brohi, [3] Tariq Rahim Soomro
[*13] *Institute of Business management, Karachi, Sindh, Pakistan*
[2] *Bath Spa University, Ras Al Khaimah, UAE*

***Abstract*- Internet of Things (IoT) is the future of the Internet. It spins around the idea of interweaving of sensors, actuators and their interconnectivity. Many proposed models are on the way. One of the most promising platforms for envisioning Internet of Things is the Fog Computing. Smart city is one application domain where the Internet of Things is greatly impacting the human lives. A defining module in such a city would be its transportation system. In such a scenario, there would be an effortless intermingling of IoT enabled devices. Since the concept is still in its infancy, huge challenges lie ahead. The paper elaborates what are the bottlenecks in materializing such a concept. It further examines the Vehicle to Internet connectivity paradigm. It then proposes an architectural framework for connected travelling. The paper concludes by providing a detailed model to resolve few design issues.**

Keywords: Internet of Things (IoT), Fog Computing, Cloud Computing, Smart Cities, Connected Vehicle.

I. Introduction

The idea behind the smart city is a recent and a modern one. There exist many attempts to define a smart city, yet none is completely agreed upon [1]. It is an application domain for Internet of Things. The focal point for a smart city is its seamless connectivity to the Internet. At present, metropolitan planning and its quality does not depend on physical infrastructure but also on communication infrastructure and real-time data analysis [1].

One of the defining modules for such a city would be its transportation system. In such a system the cars would be fully connected. A fully connected vehicle is a rich network of sensors, actuators and drivers, all connected through the Internet [2]. Each car must be uniquely identifiable. This identification is either through RFID[4] tagging or more recently through valid IP addresses. The most recent advancement in this regard is the IPV6, the extended IP addressing scheme that enable everything in the world to have valid IP. This facilitates location tracing, on the go Internet connectivity and tracking in case of sudden accidents. It is so since the car can be completely traced over the Internet. The cars need to be much more reliable for both the drivers and other travelers. A fully connected vehicle essentially must offer more fulfilling possession [3].

Much progress is already in the pipeline. Cars are progressively turning more intelligent. By 2018, it is expected that one in five cars would be self-aware. It implies they would be able to share their information. This information sharing would be among them and to the Cloud: the Internet Service Provider.

The introduction of 4G and consequently 5G networks will further facilitate the scenario. However, an IoT based solution providing uninterrupted Internet connectivity is the need of the day [3]. Further, it is expected that by 2020, 26 billion devices will be connected to the Internet. It is a defining leap since its beginning in 2009 [4], [5]. The availability of Internet based sensors for majority of devices by the end of 2025 is greatly anticipated [5].

Vehicular Adhoc Network (VANET) provide another view in the possible implementation of fully connected travelling. These are specialized cases of Mobile Adhoc Networks (MANET). This network specifies nodes as travelling, dynamic entities i.e.

[1] urooj.yousuf@iobm.edu.pk
[2] mnbrohi@bathspa.ae
[3] tariq.soomro@iobm.edu.pk
[4] RFID: Radio Frequency Infrared Detection

vehicles. The key feature of this topology is mobility. Moreover, vehicles not only communicate with each other but also to the cellular towers. The communication can provide updates on traffic conditions, infotainment and vehicle's individuality [6] . Again, these cellular towers could be the Cloudlets, the mini versions of the Cloud that provide internet connectivity on the go. These devices are essentially the Fog devices, another way in which the Internet of Things could be realized since there are many intermittent connectivity issues over the Cloud platform. Security concerns and data mishandling are another threat to Cloud mitigation. Moreover, Cloud services are hefty and are less flexible over the Client end.

The paper covers the model transportation in a smart city. It progresses to focus on the connected cars, the cars of the future. The research scope is a proposed framework for Vehicle-to-Internet connectivity

The paper is organized as follows: Section 2 covers the literature review. Section 3 covers materials and methods. Section 4 covers results and findings. Section 5 covers the discussion and future work.

II. LITRATURE REVIEW

Smart cities are the cities of the future. They envision a concept of Urban Modernization and advancement in the living standards. It is essentially a concept that is near its realization. One of the main module in such a city could be its smart transportation. A connected car is to be considered a model for transportation in the below research. A model scenario in which the car automatically alerts the nearest police station in case of accident is discussed in greater length. Few implementation details are also defined.

2.1 Smart City-A Glance

The concept of "Smart City" is a recent and novel one. There is still ambiguity over its common definition. Many definitions exist in literature. Historically, the greatest focus was given to the communication infrastructure of the city. This was early 1990s when information technology and communication industry were merging. According to a research conducted at Vienna University of Technology, six focus areas /axes measure the "smartness" of a city. These include:

- Smart Economy
- Smart Mobility
- Smart Environment
- Smart people
- Smart Living
- Smart Governance [1]

As described in the literature, the concept is being used throughout the world with varying meanings and perspectives. The word "smart" is assumed synonymous with "digital" "intelligent" or "connected" [7]. Smart city is also termed as "knowledge city", "virtual city", "ubiquitous city", "sustainable city", "wired city" or "digital city" etc. In short, city connected with an infrastructure based on ICT is termed as a Smart City [8].

The literature concludes that a smart city is essentially an Internet-connected city, wherein every element is uniquely identifiable and addressable over the Internet. It is illustrated in detail in Figure 2.1 below.

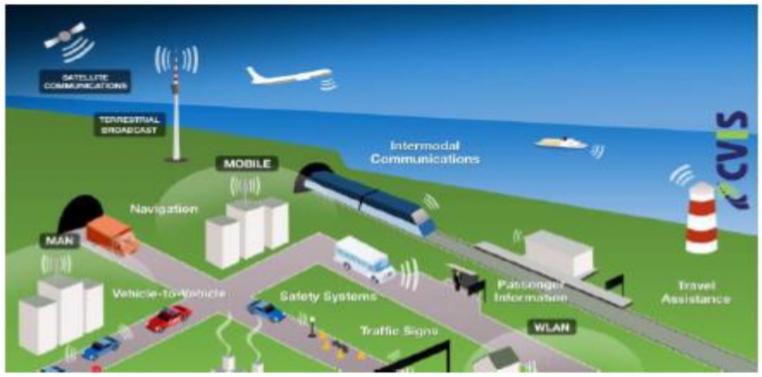

Figure ***Error! No text of specified style in document.****.1: The Conceptual Smart City* [9]

Smart cities as latest research topics are further supported by advancements in technologies such as Artificial Intelligence and Communication technologies [10].

2.2 Connected Travelling

Connected travelling is a concept that forms the core of transportation system in a smart city. To envision such a city, there are many bottlenecks. One of them is the issue of traffic congestion. It has a severely negative impact on the daily lives and work routine of the citizens. Urban planners are deciding every possible solution to avoid traffic congestion. Another major problem is that of information monitoring and updating in case of vehicle accidents [11].

The term “Connected” refers to the state of a vehicle (car in our case) that ensures its link and traceability to its surroundings [12]. This is ensured due to the presence of a large number of sensors, actuators and associated software infrastructure as well as the underlying network connectivity. The definition is similar to Auto Connected Cars. Here the software applications are numerous such as traffic safety and efficiency, infotainment, parking assistance, roadside assistance etc. Currently, the latest vehicles that include Interactive Driver-assistance Systems (ADASs) and Co-operative Intelligent Transport Systems(C-ITS) qualify for the definition of connected vehicles [12].

A major advantage of the connected vehicles is their ability of context and location awareness. These features ensure that the automobile under consideration is safer and more reliable. This feature is ensured through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. This enhanced technology can be based on vision/camera systems, sensor technology or vehicle data networks. Supporting characteristics include adaptive cruise control; automate braking, connectivity to the smart phones and driver alerts [2], [12]. It is discussed in detail in the subsequent section.

According to a research conducted by Centre for Automotive Research, “the average car now contains 60 microprocessors and more than 10 million lines of software code-more than half the lines of code found in a Boeing Dreamliner airplane”. That is huge leap since the advent of the automobile industry. Consequently, the introduction of Wireless networks, WiFi and4G-LTE networks have further improved the possibility of having connected vehicles [3]. Another important concept in this regard is that of intelligent vehicles and vehicular cloud.

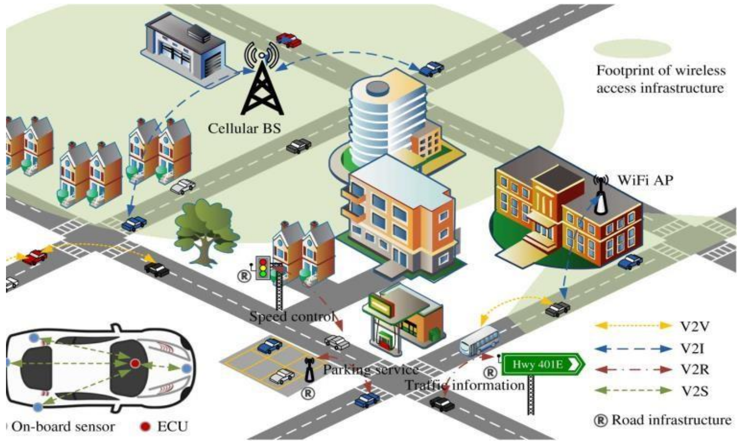

Figure ***Error! No text of specified style in document.****.2: Connected Travelling* [13]

Intelligent vehicles or intelligent connected vehicles face major implementation issues, such as security threats and intermittent connectivity. These vehicles are phasing out the traditional vehicles gradually [14] .

2.3 Co-operative Intelligent Transport Systems(C-ITS)

Cooperative Intelligent Transport System(C-ITS) is a system of interconnected vehicles communicating wirelessly. It is so to avoid the hazardous conditions and prevent traffic accidents. It is an ongoing field of research and development. It is broadly classified into two major classes: the short-range communication technology IEEE 802.11p and cellular networks (3G) or long-term evolution (LTE). There are key differences among them. IEEE 802.11p works on providing direct communication between nodes, thereby forming a VANET. There is no access point present in 802.11p but intelligent devices (ITS-enabled roadside units) can act as broadcast units sending mobile services to nodes (vehicles in our case). Cellular networks on the other hand follow a centralized topology, thereby routing all the data to pass through a Base Station (BS). C-ITS is broadly classified into three major categories: road traffic safety, traffic efficiency and value added services. Each has requirements of their own. Speaking particularly of road traffic safety, these parameters are low latency and high reliability. Their adhesive protocols are developed in US and Europe. Examples include lane changes, emergency vehicles approaching and road conditions etc. A common linking ground for these stacks are communication technology 802.11p and other relevant protocols with lower overhead. Efficiency applications and value-added services combine 802.11p, 3G/LTE with network protocol (IPv6). Examples include channeling road traffic flow and reduced gas emissions. Value-added services may be announcements of business services such as promotions etc. Notable examples are traffic-light optimization and enhanced route guidance.

Road traffic safety and efficiency are overlapping in certain cases such as in case of a road accident. Here if a vehicle suddenly halts in the middle of road, drivers can receive guidance from enhanced route guidance application for an alternate route . Thus safety applications can trigger efficiency applications and vice versa. It is important to mention here that 3G/LTE and IEEE 802.11p are supplementary technologies in this case and not contrasting ones. Each has their own features. As already mentioned, 802.11p is independent of BSs to send information.

Information can also be sent on a targeted direction using georouting. Moreover, latency can be minimized by deploying the Ad Hoc communication mode of IEEE 802.11p. Applications that are not latency sensitive can be routed further to utilize 3G/LTE. An ideal scenario would be when a fixed ITS station utilizing 3G/LTE acts as information transmission source. It can send service update beacons to the surrounding nodes (vehicles in our case). These nodes in turn can tune in to 3G/LTE networks to receive more detailed information [13]. [6]

2.4 DSRC –Dedicated Short Range Communication

An origin of the 802.11p protocol is found in IEEE Wireless Access in Vehicular Environment (WAVE). In 2003, IEEE picked the former work done in this regard by ASTM. The enhanced work included extension of the protocol stack for supporting Internet access. The initial WAVE protocol stack included layers such as physical, datalink, network and transport. It is further sub divided into two major classes: safety applications and non-safety applications. Safety applications use unified protocol for transport and network layers, WAVE short-message protocol. It is derived from IEEE 1609.3 and 1609.2. The non-safety applications utilize traditional Internet Protocol (IPv6), UDP for connectionless services and TCP for connection-oriented services. IEEE 1609.4 for multichannel operation according to FCC frequency regulations is used at datalink layer. The MAC and physical layer are derived from IEEE 802.11-2012.Both safety and non-safety applications share same data-link and physical layer for transmission. The ‘p’ in 802.11p stands for vehicular “profile”, which was incorporated in latest version of IEEE802.11-2012 [13], [6].

To dig deeper, IEEE 802.11-2012 comprises of two further topologies: infrastructure basic service set (BSS) and Independent BSS (IBSS). BSS ensures that the data is routed centrally through a central access point even when the two stations are in physical proximity. IBSS, on the other hand comprises of directly communicating nodes forming an Adhoc Network. Both topologies support roaming services and require timing signals to synchronize between the participating nodes via beacons. The identification is done using a unique BSSID. Association and authentication is not required in Adhoc mode. Here the communication can take place in unauthenticated mode. It is quite contrary in case of IBSS. Here credentials are of utmost importance. At the MAC sublayer, authentication, association and security are disabled in 802.11p (Adhoc) mode. The purpose of avoiding these is to speed up the process of information exchange in a VANET since validation is a costly procedure [13], [6].

This method is highly effective in case of VANETs as nodes in a VANET are highly mobile and operational at high speeds. Moreover, if a transition begins, nodes may run out of range before it is completely executed. Another point worth considering in this case is the scanning restriction. It implies that active and passive scanning of BSS and IBSS are halted. Thus, there is no scanning frequency for stations to join a specific network. A fixed, agreed-upon frequency channel for implementation of 802.11p is decided early. Quality of Service (QoS) is provided at the MAC sublayer. It is achieved using Enhanced Distributed Co-ordination Function (EDCF). This DCF is based on Carrier Sense Multiple Access (CSMA) with collision avoidance algorithm. It is important to note that IEEE 802.11p uses Orthogonal Frequency Division Multiplexing (OFDM) on the physical layer that supports the QoS [13].

Another term used for IEEE 802.11p or Adhoc part of WAVE is Dedicated Short Range Communication (DSRC). This term is more common in United States or Australia. Another term interchangbly used is Electronic Toll Collection (ETC). This term is more commonly used in Europe or Japan. DSRC is essentially a master-slave system functioning on 5.8-GHz frequency band. Its components include a fixed roadside unit (RSU) and short-range communications. It is important to note that after the introduction of WAVE, DSRC generally refers to IEEE 802.11p-centred VANET working with frequency range 5.9GHz. Master-slave ETC system is referred as CEN-DSRC. The operational frequency here is 5.8GHz [12], [6].

2.5 Vehicle-to-Internet Connectivity: Drive thru Internet

Internet connectivity is a mandatory feature of the modern vehicles. It is a recent field of research. The automobile industry has timely evolved to meet this essential requirement. There are many off-the-shelf technologies and developments targeting uncaptured market of Internet-Connected Cars. Equivalent developments in academics focusing on development of accurate and up-to-the-mark solution discovery are on the way. There are many different names for the same technology: “The Internet Multimedia on the Wheels”, “Web on wheels” and “the Network Vehicle [13].” Due to wide-scale research in fields such as automobile industry, telecommunications and electronics, this concept is near visualization.

A promising field in this regard is that of Wireless access technologies. It is one of the major implementation scenario for visualizing Drive thru Internet. Two sub areas include Cellular networks and WiFi. Cellular networks e.g. 3G or 4G-LTE can provide fast, cheap and trustworthy Internet connectivity. However, these services come with a cost. Another perspective could be the installation of low-cost roadside Access point (AP) for roadside Internet connectivity. This approach has been demonstrated in many researches. Connecting vehicles to the Internet using a cellular network is discussed here in detail. There are two wider approaches to this: brought-in or built-in solutions as considered by the automobile industry [13].

Brought-in Connectivity implies that users are tethering their smart phone to the car. It means there is no in built mechanism inside the car. Rather, an outside agent brings in Internet connectivity using 3G/4G cellular packages. A popular tethering technology is MirrorLink and is supported by Car Connectivity Consortium (CCC). It is an organization that calls leading automobile developers (e.g. Toyota) and ICT manufacturers (e.g. Sony) to develop a “phone-centric car connectivity.” Using MirrorLink, a Wi-Fi enabled device (such as a mobile phone) can connect to the Vehicle Infotainment system. The resulting Internet connection would enable the vehicle to gain immediate and limited access to the Internet. A major advantage of using aftermarket services is the absence of pre-embedded infotainment system [13].

Built-in Connectivity: This option is largely left unexplored. This option implies that the cellular service and the on-board Infotainment system are integrated. Here the connectivity to the Internet in embedded into a cellular connectivity module. BMW ConnectedDrive combines objects from different online applications such as driver assistance and call center services etc. to provide Internet connection for In-Vehicle Mobile Services. Another related fine example is AudiConnect. It connects topmost available cellular technology 4G LTE to connect the cars to the Internet. This concept of connecting cars to the Internet is termed as “Drive-Thru Internet” [13].

The concept of “Drive-Thru Internet” is an interesting one. Here Wi-Fi, a popular broadband wireless technology offers the “last-hundred meter” backhaul connectivity. With millions of Wi-Fi hotspots deployed throughout the world, Wi-Fi can offer a possible solution to vehicular Internet access at a reduced cost. Few of the experiments conducted with respect to feasibility of Wi-Fi are discussed here. The in-built Wi-Fi radio or Wi-Fi-enabled mobile devices can be connected to the Internet while they are in the coverage area of Wi-Fi hotspots. This is the ground concept behind “Drive-thru Internet.” This concept is elaborated in figure 2.3 below.

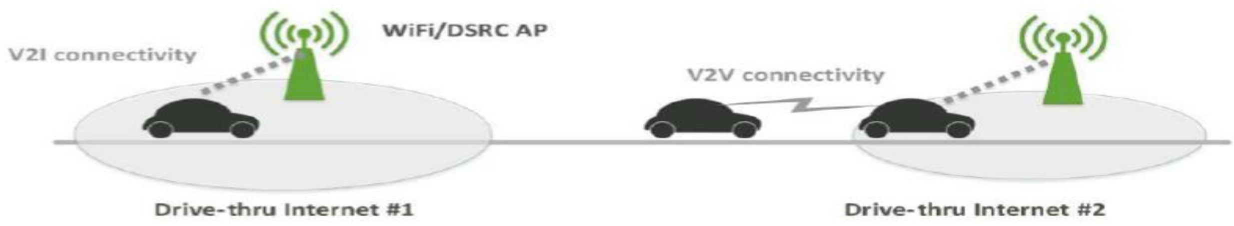

*Figure **Error! No text of specified style in document.**.3: Drive-thru Internet [11]*

As can be seen, this type of Wi-Fi access can provide a low-cost data pipe for the vehicles. Further, recent advances in Passpoint /Hotspot 2.0 improve performance of Wi-Fi for connectivity and seamless roaming. The hotspots and the Wi-Fi for providing the Internet are mushrooming, thereby ensuring the possibility of a large-scale, Urban Wi-Fi network. Mountain View has an Internet-based City network, Google Wi-Fi.

Characteristics and Challenges: The indoor Wi-Fi network serves stationary or slow-moving users. It is not scalable for large number of users and rapidly changing topologies. To elaborate further, moving vehicles usually with high speeds provide a limited and short time period for connection. This is ideally a fraction of several tens of seconds. This greatly limits the amount of data transferred in a single instance. To understand fully, few parameters are used as reference. The overall connectivity radius for a roadside Access Point is nearly 500-600m, corresponding connectivity time of about 18-21 sec for a vehicle moving at 120km/h. To add further, time spent in Wi-Fi connectivity, association and IP configuration is also to be considered. Secondly, significant factor is the high degree of channel fading and shadowing, resulting in significant wireless loss. Thirdly, Wi-Fi protocol stack is not significantly designed for a highly mobile environment [13].

Improvement Strategies: As discussed above, the average throughput of the drive-thru is limited in the real world. Contributing factors are high automobile speed, intermittent connectivity issues and potential channel contentions. It influences the Quality of Service negatively.

To counter balance these effects, few solutions in the literature include:

- Reduction in connection establishment time
- Improvement on the transport layer protocols to deal with intermittent connectivity issues and wireless transmission losses
- Enhancing MAC protocols for high mobility
- Designing tradeoffs to deal with frequency interruptions
- Using a multihop vehicle-to-Vehicle communication capability for data traffic relaying
- Optimal deployment of Wi-Fi access points. [13]

2.6 Internet of Things (IoT) and Internet of Vehicles (IoV)

There are currently 20 billion connected devices on the earth. It is a concept that gives rise to "Internet of Things" or more recently "Internet of Everything". It implies effortless weaving of sensors and actuators in an environment that is context aware, intelligent and flexible. One sub area of interest in this paradigm is that of Internet of Vehicles or Vehicular Cloud [15].

A smart and connected vehicle is equipped with sensors that generate huge amount of data in fraction of the time. Simultaneously, the road is fine grained with smart dust components, identifiers and microcontrollers. These elements together make up a "Vehicular Grid" or a "context-aware" transportation system. This is a baseline concept for Internet of Vehicles or Vehicular Cloud. Vehicular Cloud is an abstraction that encompasses all protocols, services and communication platform required by the grid to perform effectively. Futuristic approach suggests that addressing and access to the neighboring devices, context awareness and inter vehicular communication will enhance system performance and driving accuracy by many folds. This will provide a well-coordinated platform for data aggregation, fusion and sharing [15].

These demands are due to increased data volume. A key concept in this regard is that of Automotive IoT or Internet of Vehicles. Broadly speaking, the Automotive IoT is classified into five further sub-classes:

- Infotainment :entertainment and information based on personal preferences
- Navigation: information about traffic routes, updates and route planning
- Safety: Smart SOS, roadside assistance
- Cost-efficiency: Insurance updates, maintenance
- Payment: Electronic toll collection, parking reservation and payment [3].

The concept behind Internet of Vehicles stems from the main concept of connecting "things" through Internet. Here the concept is applicable to all automobiles and communication entities that are connected through an all IP-based network [16]. Such a network ensures information exchange capability and resolution of contrasting issues resulting in an efficient, safe and eco-friendly transportation. To materialize this concept completely, following areas need to be considered:

- An event-based approach that can be procured through the analysis and study of various Internet connected interactions and scenarios.
- Energy Saving and Fuel Efficient vehicles in terms of security and traffic management. Smart algorithms for such a system are yet to be developed.
- Versatile data acquisition and aggregation from varied input sensors and platforms. These input devices may or may not be connected directly to the network.
- Modelling the scenario using stakeholders such as driver, vehicle and environment modelling.
- Producing outputs as per scenario basis for enhancing the performance of these Internet-connected vehicles. These outputs must be service oriented effective solutions for a huge, high-speed Internet connected network namely Internet of Vehicles.
- A complete functional and system architecture for IoV based on existing standards and further extensions if needed [16].

2.7 Fog Computing

Fog is a cloudlet located nearer to the ground. It is essentially a mini-cloud, focused on sending and receiving data over the Cloud. The concept of fog is to entertain majority of device requests locally instead of sending them over the Cloud. The Fog networks become significant as Cloud services face issues of latency and delay. Moreover, Cloud services face issues of latency and delay. Fog computing implies computing at the edge of a network.

Key attributes of the Fog include:

- Low latency and location awareness
- Wide-spread geographical distribution
- Mobility

- Very large number of nodes
- Importance of Wireless networking
- Heterogeneity [17]

These features make Fog an ideal platform for enabling Internet of Things. Thus, Fog networks are providing an ideal platform for enabling Internet of Things. Other applications include Smart Grid and broadly speaking a Wireless Sensors and Actuators Network (WSAN). These all are major applications to be deployed in a Smart City [17].

The figure below envisions the Internet of Things and Fog computing. As discussed above, Fog computing provides a modular and efficient platform for envisioning Internet of Things. It is important to notice here that Fog has certain features that make it a non-trivial extension of the Cloud [17].

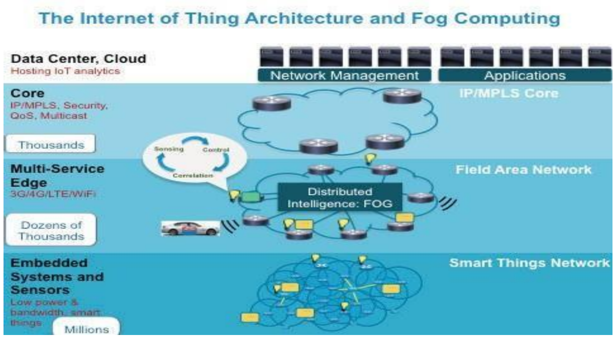

*Figure **Error! No text of specified style in document.**.4: Internet of Things and Fog Computing* [17]

2.8 Fog Computing and the Internet of Things

This section concludes the literature review by describing the Fog as a possible platform for enabling Internet of Things. There are multiple application areas where Fog can be significant. Major areas of Interest are as follows:

- Connected Vehicles
- Smart Grid
- Wireless Sensor and Actuator Networks [17]

A specific scenario of interest is that of Connected Vehicle. A connected vehicle in itself is a rich network of sensors and actuators and their interconnectivity. These include vehicle-to-vehicle, vehicle to access points and access point to access point. Fog stands as a major communication interface in this scenario [6]. These include mobility and location awareness, low latency, heterogeneity and high speed for Real-time connections. Another context is the smart traffic light system. A smart traffic light system could detect the presence of pedestrians and bikers and can determine the distance and speed of cars. This information can be analyzed to estimate time for red light or the green light. A co-ordination with neighboring sensors can be deployed to do the Real Time analysis (altering the cycle time based on traffic conditions).The clustered data could be sent to the Cloud for Long-term storage and analysis. The modular and modifiable architecture of Fog makes it an ideal candidate for providing Internet connectivity to connected vehicles and envisioning Internet of Things [18].There are key challenges in traffic management against which Fog can be an ideal solution provider. These include:

- Slower emergency response time in case of accidents
- Unpredictable scenarios such as accidents and weather conditions.

- Data is distributed among various departments and is thus scattered.
- Stringent bandwidth and increasing complexity [19]

Possible solutions for these challenges can be:

- Fog architecture has flexibility to connect all different unconnected services and devices, roadside sensors and on-board devices.
- Every authority involved in traffic management and monitoring could set up their individual Fog networks.
- Gateways can share information effectively among each other.
- Fog nodes can reduce cost by accumulating various requirements such as storage and security under a single roof [19].

Technological possibilities provided by the Fog are:

- Automotive-based nodes can gather data from different sensors present in the car and connect to other Fog nodes e.g. EMS Cloud.
- Roadside nodes can collect data from the vehicles and connect to other Fog nodes.
- Regional nodes can aggregate big data for sending to the Cloud for long-term analysis [19].

2.9 Vehicular Cloud Computing

VCC is an adaptation of the Mobile Cloud Computing that stems from original Cloud Computing. There are obvious advantages to this approach. The traditional approach requires uploading all contents to the Internet. This would be costly and time-consuming. A similar approach is applicable in terms of downloading and searching contents over the Internet. Vehicular Cloud Computing approaches the problem differently. It focuses on developing Clouds for the Vehicles wherein the data is collected, maintained and consumed locally or to the nearby, neighboring vehicles [15]. A model for connected travelling, a connected car is shown in the Figure 2.5.

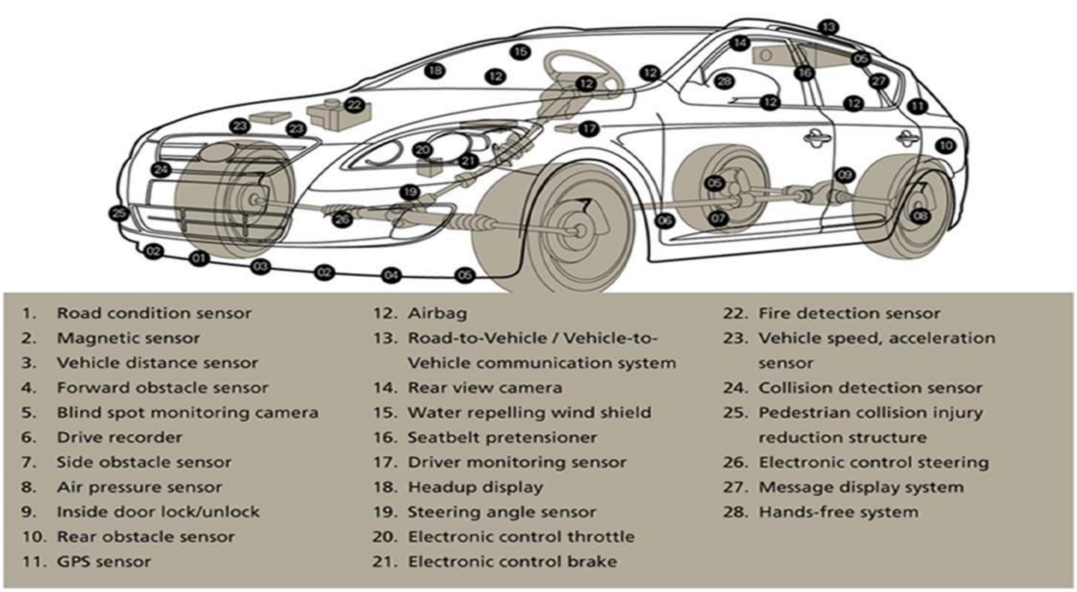

Figure ***Error! No text of specified style in document.****.5: Connected Car-A Model for Connected Travelling* [9]

As can be seen from the above figure, the car has as rich collection of various types of sensors. The future cars would be a rich network of such sensors. Their interconnection with each other and to the Cloud would form Internet of Vehicles: a subsystem of Internet of Things (IoT).

2.10 Mobile Ad hoc Networks (MANETs) and Vehicular Ad hoc Networks (VANETs)

Mobile Ad hoc Networks (MANETs) have several distinguishing features that make them ideal for envisioning a connected vehicle concept. Characteristics such as ever changing logical lay out, limited bandwidth and battery stringency are the defining features. Such features are truly an embodiment of the road and the vehicles. Since MANET is an autonomous system, participating nodes could be located anywhere, on any vehicle. In our case, a connected car is the dynamic node. MANETs can be formed as Inter-vehicle communication network .They can also be envisioned as Vehicle-to-Internet connectivity network. A special case of MANETs is VANETs where the nodes are the connected vehicles. Such a network dose not assume an end-to-end connectivity. Here the node-to-node connectivity is extravagance.

It must be noted that VANETs are not completely dynamic. The movement of automobiles and their position is relatively predictable as it is confined to the road on which the vehicle travels. This ease of predictability enhances improvement in the link selection. On the down side, the linear arrangement reduces redundancy. Bandwidth issues also arise due to traffic jams and presence of buildings, especially in the metropolitan network. VANETs can also grow potentially in size especially in the case of traffic jams [20].According to another research VANET are described differently. Nodes in a VANET must be enabled for faster data transmission. They must be productive in terms of internode communication. Broadly speaking, VANETs are classified into two major categories:

- Safety Applications
- User Applications

Safety Applications increase road and travelling safety. Deploying these applications over the VANET can significantly reduce the traffic accidents. According to some studies conducted in this regard, nearly half of the accidents could be avoided if a driver were provided with a warning just half a second before the moment of collision. Vehicular safety could play a significant role in three significant directions.

Accidents: High speed travelling is the talk of the day. The average travelling speed of the vehicles today is far more increased than past. This trend is expected to grow further. This poses safety threat to the drivers as they have very little time to react to a changing stimulus i.e.an approaching vehicle. If the vehicle could alert the driver of early warnings and signs, the accident can be avoided altogether.

Intersections: Intersections and driving at them are a major challenge for Drivers. According to U.S Department of Transportation, 45% of major crashes and 21% of fatalities are due to intersection in 2003.These numbers can be reduced significantly if the drivers were alerted of the near danger [20].

Road Congestion: Traffic congestion is another bottleneck in the current system. Safety applications could be useful in guiding the drivers on paths of least congestion. This in turn

would lead to smooth flow of traffic and indirectly lead to lower probability of roadside accidents.

User Applications ensure value-addition to travelling. They can supply information, entertainment and latest updates depending on the individual choices. They are further classified into following two sub classes:

Internet Connectivity: Persistent Internet connectivity is the need of the day. Most of the users demand and expect the Internet to be fully available while travelling. It implies that occupant could continue their work over the Internet even while driving. This eliminates the need for a specific location for business purposes.

Peer-to-Peer Applications: The idea here is to share music, videos and play online games while being on the move. Movies from specified servers and other user-centered applications can also be played [20].

To conclude the discussion about VANETs, users must remain completely unaware of the problems inherent in VANETs. VANETs present a promising field of development and research.

III. MATERIALS AND METHODS

The research approach adopted here is qualitative research supported by literature review, analysis and architecture. This pattern facilitates an almost realizable and nearly predictable design for model transportation in a smart city. Majority of the papers published are during 2015-2021.This section explores and proposes an architectural model for a connected city. It begins with the detailed analysis of the proposed architecture. Next, it proceeds to explain the various architectural views. It concludes by providing a possible list of hardware, software and networking tools that can be helpful in the final implementation.

3.1 Architectural Goals and Constraints

The proposed architecture for the system has following goals:

- To provide a sustainable transportation model for a smart city
- To facilitate the design process for such a vehicle
- To make roadside travelling more secure and reliable
- To provide internet connectivity to the entire area within the radius of the system
- To facilitate the location tracing of any vehicle in case of an accident
- To automatically send the relevant information about the driver/passengers in case of an accident to the nearest police station.

The major design constraints are:

- High availability
- Interoperability
- Performance
- Scalability

3.2 Architectural Design Pattern and Tactics

The design pattern used for this framework is *Broker Design Pattern*. This design pattern is ideal when there is a collection of services distributed among multiple servers. Visualizing such systems is complex as the major design concerns are interoperability, connectivity and performance. A driving question is the structure of the distributed software. It should be designed such that users do not need to know the location of the service providers but are able to switch dynamically from one access point to another [21].

To achieve this functionality, the broker pattern introduces the concept of an intermediary. It separates the users of the service (clients) from the providers of the service (servers) by providing an intermediary. The client queries the server via a broker. The broker then forwards the request to the server to be entertained [21].

Figure 3.1 explain the broker pattern in detail.

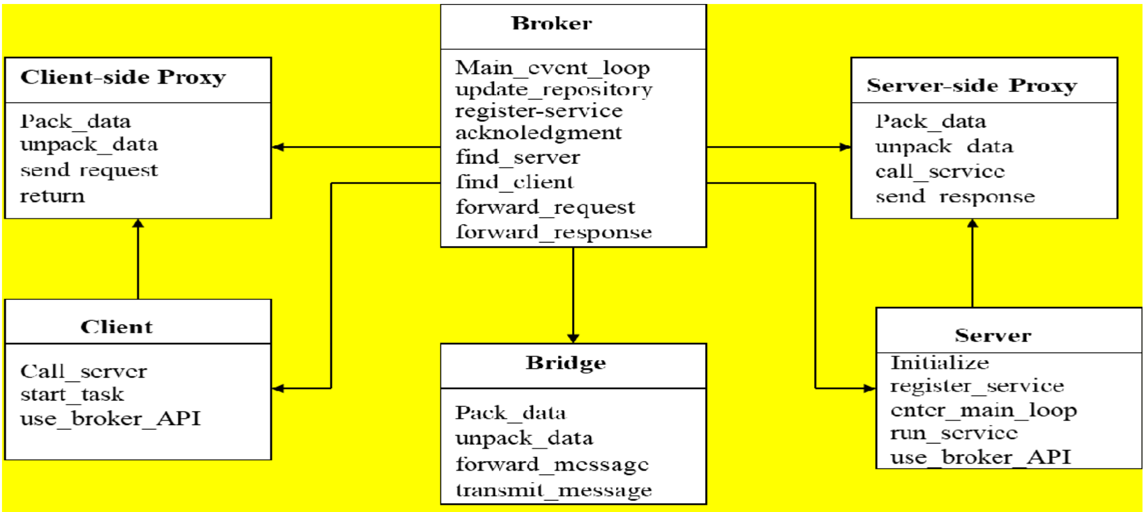

*Figure **Error! No text of specified style in document.**.6: Broker Pattern and Its Major Classes* [22]

- Six different building blocks of the pattern include :
  - Client
  - Server
  - Broker
  - Bridge
  - Client-side proxies
  - Server-side proxies [22]

Table 1: Broker Pattern and responsibilities [22]

Participating Component	Responsibilities
Servers	application specific servers
Client	applications that access servers
Broker	acts as a messenger to transmit requests from clients to servers and transmits response and exceptions to client
Bridges	layer between two brokers, used to hide each side implementation details
Client-side proxies	represent layer between client and bróker to provide transparency
Server-side proxies	responsible for receiving requests: unpacking messages ,unmarshalling parameters ,calling appropriate service, marshalling results and exceptions to client [22]

As can be seen above, the client in this case is the connected vehicle that wishes to connect to the Server requesting for a specific service. A special case could be the location update in case of an accident. There is one common module among three participants: Use BrokerAPI ().All these modules are explained in detail in the next section, which covers the different architectural views.

3.3 Architectural Representation

Accurate modelling of the framework requires that it be viewed from different implementation angles. A number of varied views permit a reliable design. Due to these reasons, the proposed framework is studied from five different approaches. These approaches are depicted in Figure 3.2 below. These include Use-Case View, Design View, Process View, Component View and Deployment View.

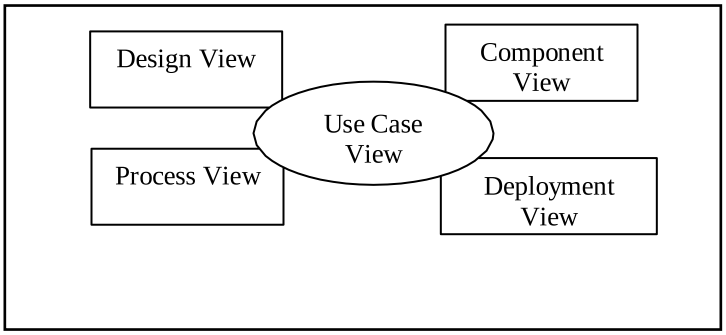

*Figure **Error! No text of specified style in document.**.7: Different Architectural Views*

3.3.1 Architecturally Significant Functional Requirements-Use-Case View

There can be multiple use-case scenarios of the system. This section deals with the core Use Case that define the Broker Pattern for the Architecture. The Figure below depicts the functional requirement of the framework.

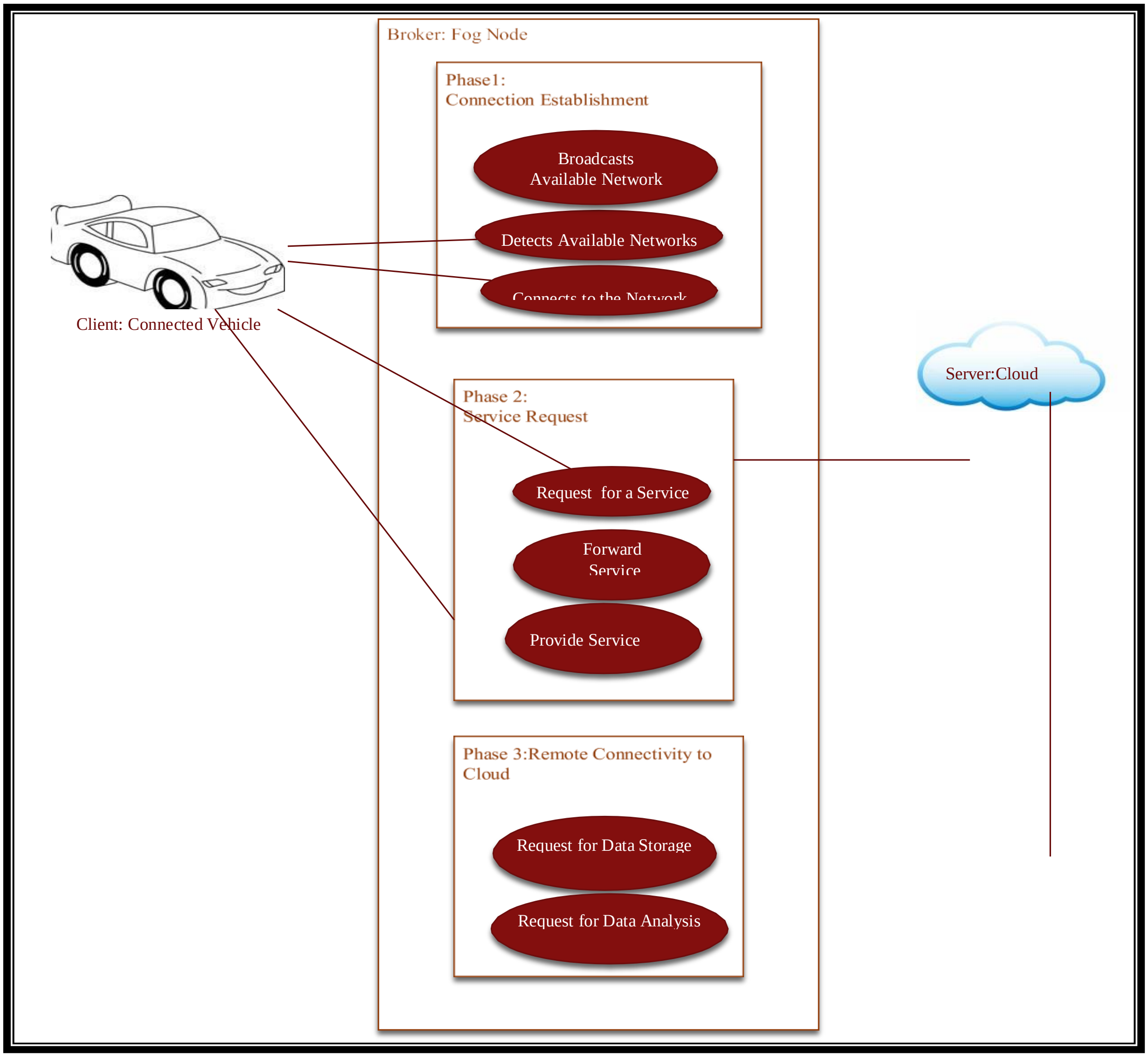

*Figure **Error! No text of specified style in document.**.8 Use-Case View*

The sequence of services is as follows:

Phase 1

- The Fog node broadcasts the available networks.
- The Connected Vehicle detects the available networks.
- The Vehicle requests for a connection establishment.
- The Fog node approves the connection.
- The connection is established.

Phase 2

- After connection establishment, the Connected Vehicle requests for a specific service.
- Depending on the type of service, the request is either entertained locally through a local Wi-Fi network.
- If the request is a bandwidth intensive application, the request is routed to the Cloud data server (Cellular Network).

Phase 3

- Applications that are less sensitive to latency are sent to the Cloud.
- These applications may include requests for data storage and analysis.

3.3.2 Architecturally Significant Non Functional Requirements-Utility Tree

These requirements have a profound impact on the quality of the proposed framework. These quality requirements are captured using the Utility Tree Diagram. Figure 3.3 below describes the quality attributes of the system under consideration.

The utility tree is further broken into sub module. Each node describes in detail the impact of each quality factor precisely.

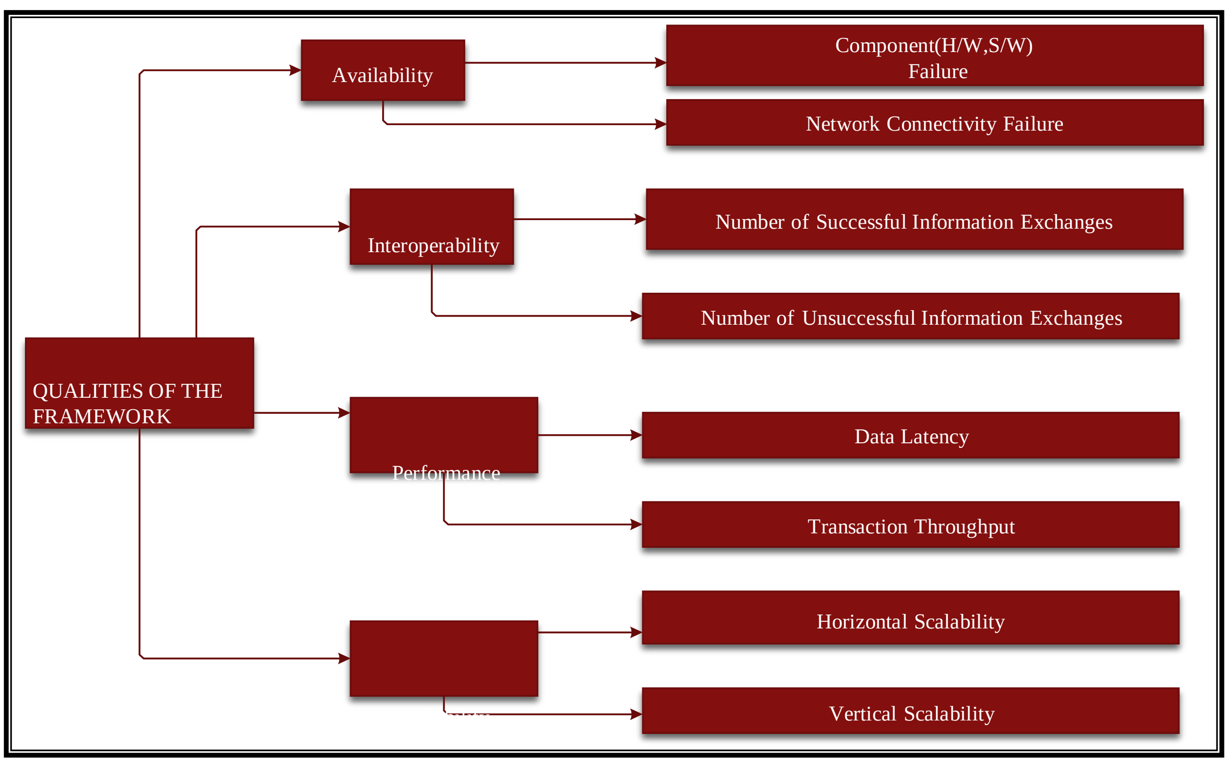

*Figure **Error! No text of specified style in document.**.9: Utility Tree of the Framework*

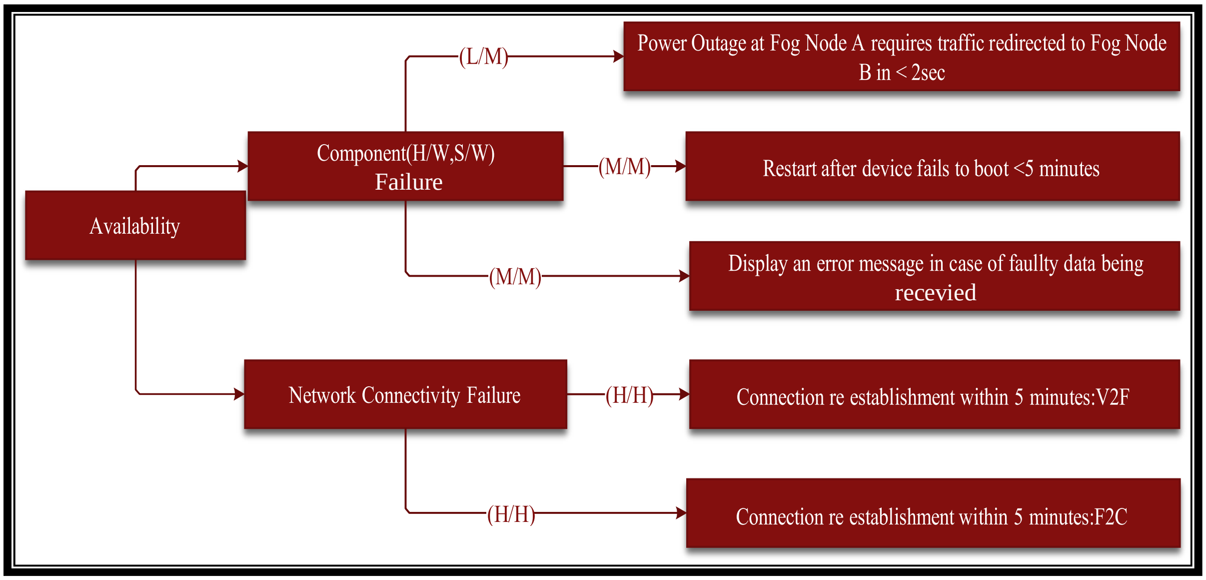

*Figure **Error! No text of specified style in document.**.10 Utility Tree for Availability*

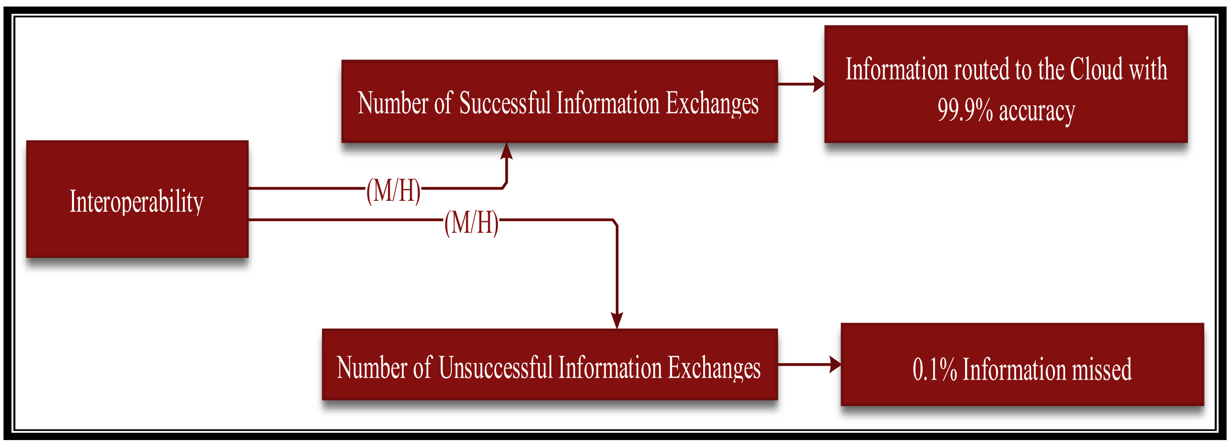

*Figure **Error! No text of specified style in document.**.11: Utility Tree for Interoperability*

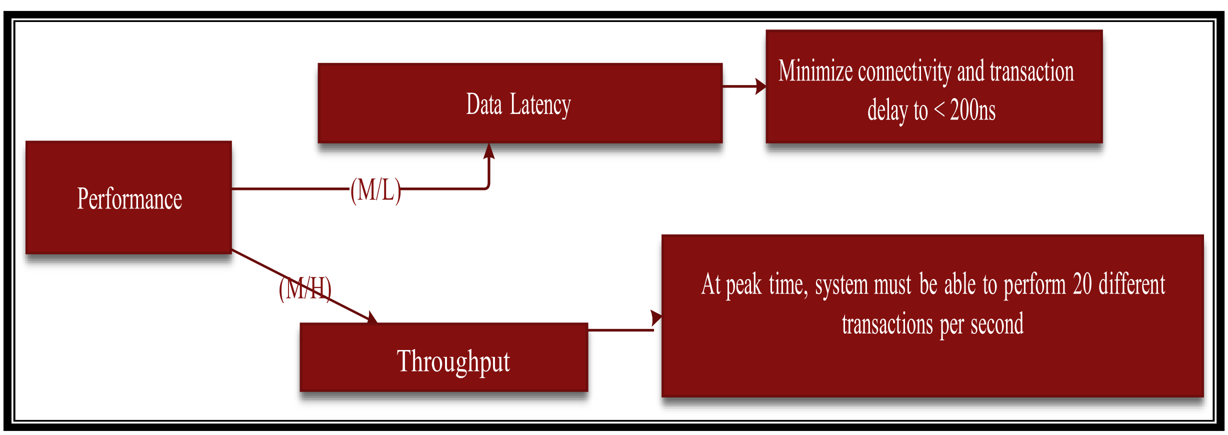

*Figure **Error! No text of specified style in document.**.12: Utility Tree for Performance*

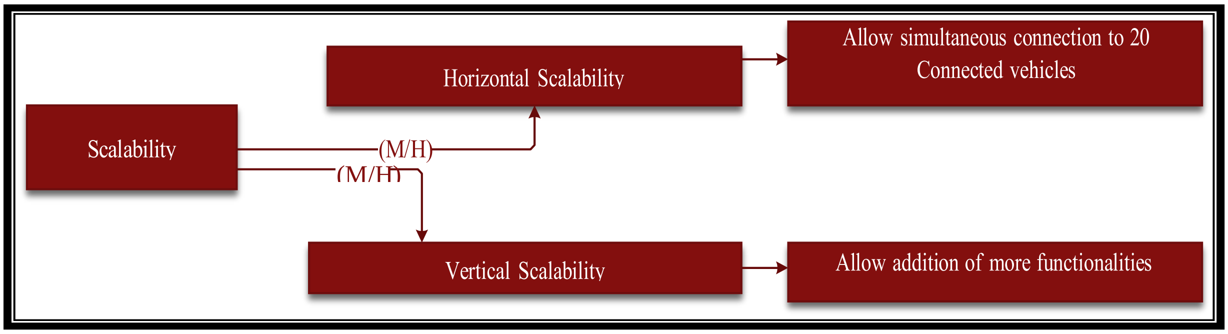

Figure ***Error! No text of specified style in document.****.13: Utility Tree for Scalability*

3.3.3 Design View

Broker Solution-1: This specific design pattern defines the runtime component, broker. In case of a Connected Travelling, this broker is essentially a Fog node that acts as an intermediary between the Connected Vehicle and the Cloud. The user of the service (client) is the Connected Vehicle and the provider of the service is essentially the Cloud. Thus, the continuum from the Vehicle to Cloud can be established successfully. One of the drawbacks of a broker pattern is that it introduces latency. Hence, it could act as a performance bottleneck. Moreover, it could be the single point of failure, target for security attacks and sometimes difficult to test.

A significant design tactic for performance is to increase the available resources. This in turn may lead to increased cost. However, the increase in cost is marginal with respect to the boost in performance in this scenario. Another design tactic is the efficient use of resources by deploying the scheduling policy. Here the large number of Fog nodes would limit the scheduling overhead. Modifiability too can be easily incorporated in such a design. Figure 3.8 and 3.9 describe the design view in detail.

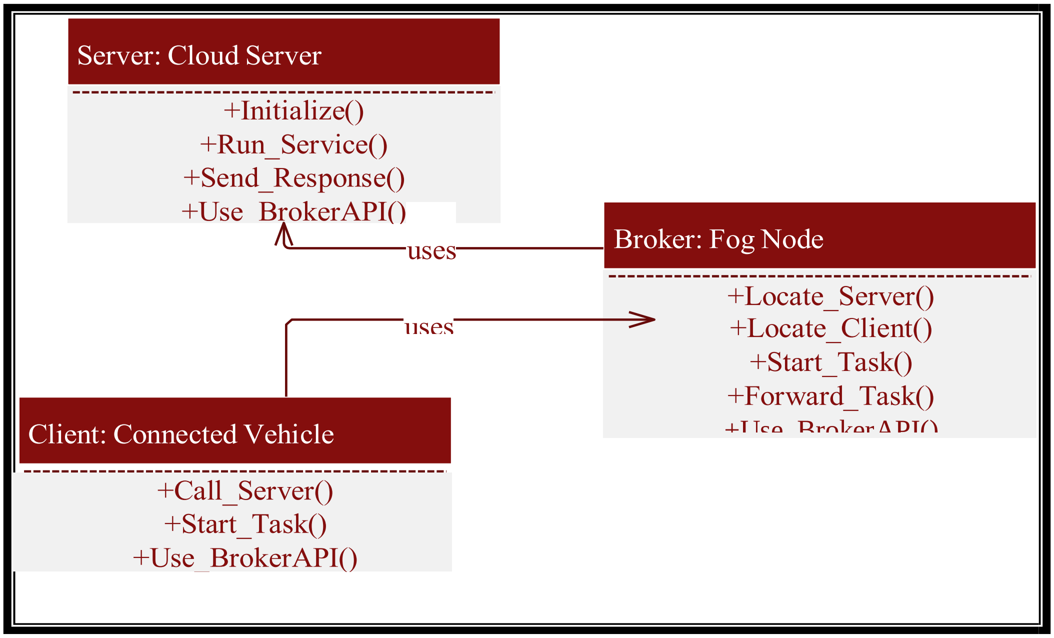

Figure ***Error! No text of specified style in document.****.14: Design View for Framework* [22]

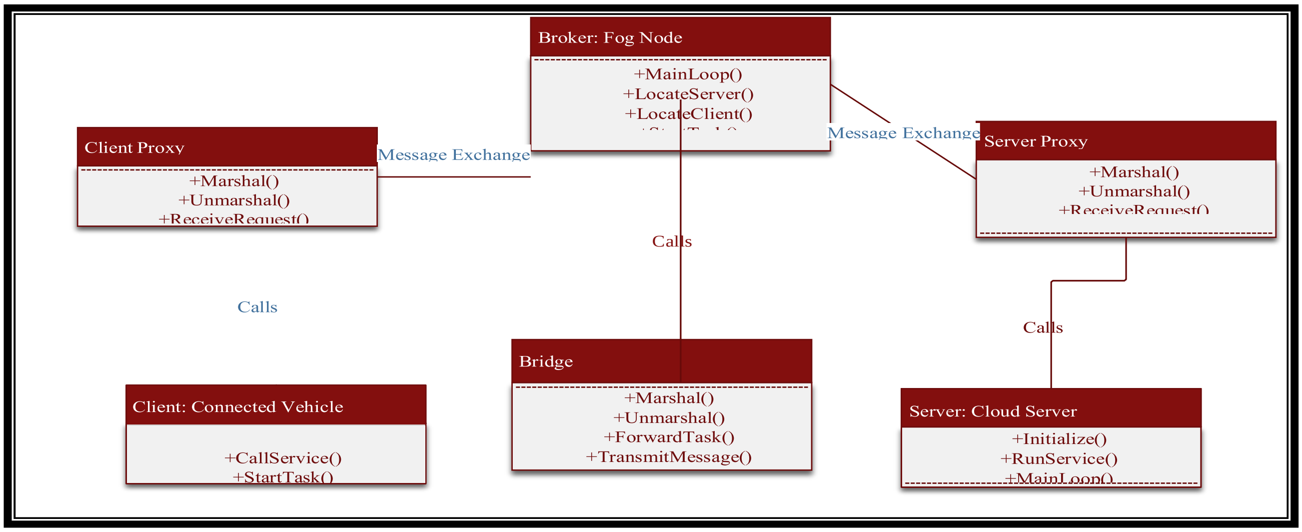

Figure ***Error! No text of specified style in document.****.15: Detailed Design View* [22]

3.3.4 Process View

Sequence and activity diagrams below depict this view.

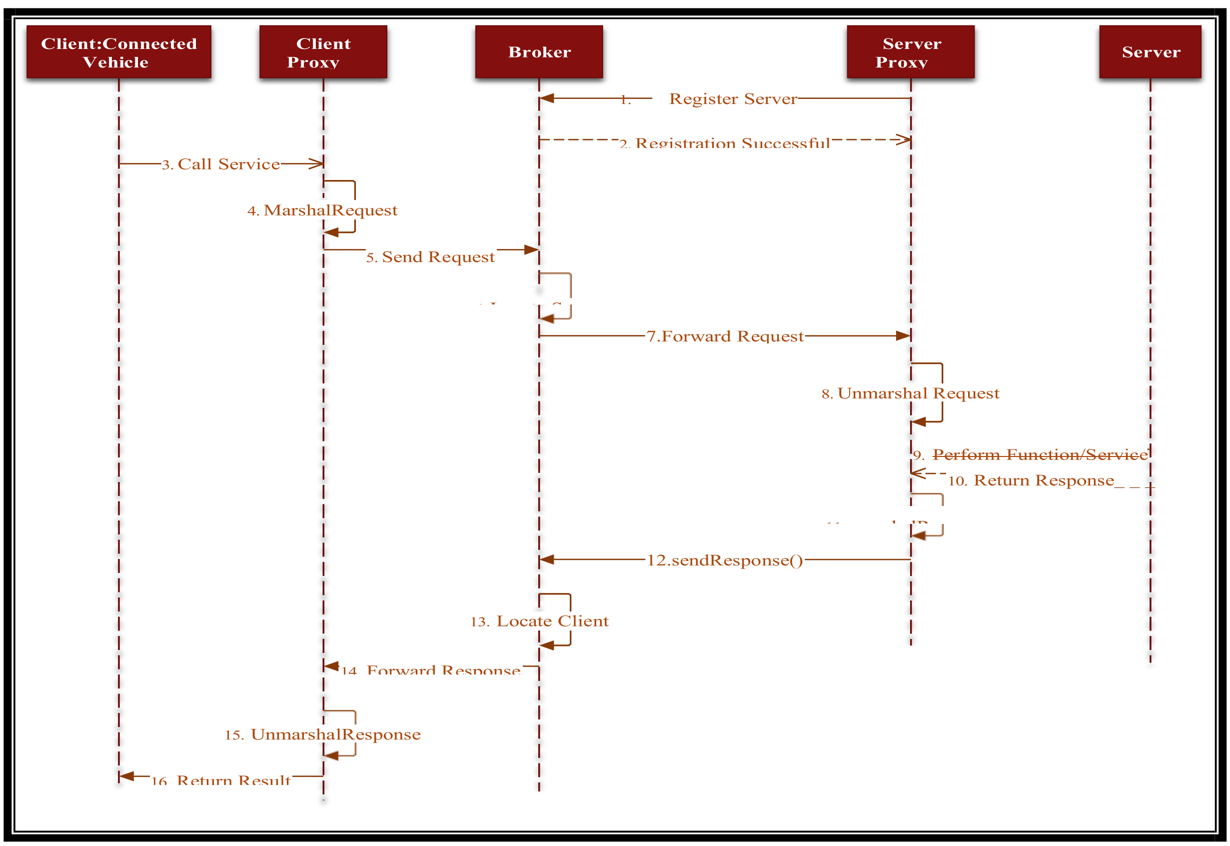

Figure ***Error! No text of specified style in document.****.16: Sequence Diagram* [22]

3.4 *Possible Devices and Their Specifications* [23]

Connected Roadways solves common safety, mobility, and operational challenges

Cisco product Description

• Vehicle router connect onboard systems to wireless DSRC onboard unit (OBU) and roadside unit (RSU)

• Ruggedized Ethernet switches provide transport connectivity to the roadside equipment components

• Hub switches for maintenance yard networks

- Cisco ASR 900 Series Aggregation Services Routers
- Cisco IE 4000 Ethernet Series Switches

Cisco 829 Industrial Integrated Services Routers

• Provides hub routing functionality management of mobility for and communications to and from vehicles

Cisco Nexus switches

• Network foundation of the Cisco Virtualized Multiservice Data Center (VDMC) solution, which provides the data center platform for all Connected Roadways back-office and centralized systems

Cisco Kinetic

• Makes it easy to connect distributed devices ("things") to the network, then extract, normalize, and securely move data from those devices to distributed applications. Consists of three modules:

- Gateway Management Module (GMM): provides cloud- based management and provisioning of the IR 829 gateways

- Edge Fog Module (EFM): Open architecture platform that enables immediate processing of data from the fog to the edge of the network

- Data Control Module (DCM): Enforces policy and is responsible for getting the right data to the right apps at the right time

IV. RESULTS AND FINDINGS

This chapter highlights the results and the findings as inferred from the literature review and comparisons. The alternate framework and its significance is discussed here in detail. As mentioned earlier the proposed framework will enhance the Vehicle-to Internet connectivity and provide drive-thru Internet to the vehicles. A software pattern, namely the broker pattern is deployed here to meet the intermittent connectivity bottleneck. Moreover, the device requests that can be entertained locally are processed at the Fog edge instead of being routed to the Cloud. Fog devices can act as broker in the system there by enhancing and enabling high speed Internet connectivity.

4.1 *Findings from Literature*

Some of the major findings from the literature sum up as follows:

- Still no common agreed-upon architecture exists that guarantees 100% Internet connectivity to the vehicles on the go.
- Many automobile developers and manufacturers are working towards individual implementations of connected vehicles. Most notable ones include Connected drive by BMW and AudiConnect by Audi [13].
- Brought-in Internet connectivity is much in practice as compared to the built-in connectivity.
- Built-in Connectivity ensures platform independence in terms of vehicles and their manufactures.
- Few experiments conducted for built-in connectivity did not yield highly positive results.
- A related experiment yielded following results (few parameters are used as reference):

- The overall connectivity radius for a roadside Access Point is nearly 500-600m, corresponding connectivity time of about 18-21 sec for a vehicle moving at 120km/h.
- To add further, time spent in Wi-Fi connectivity, association and IP configuration, channel fading and limitations in the Wi-Fi protocol stack is also to be considered [13].
- Another experiment conducted in this regard eliminated the inter vehicular communication.
- Its focus was to analyze the impact of backhaul capability on the Drive Thru Network.
- *It was evident that backhaul compatibility was the limiting factor for the network performance.* For example, with a 1Mb/s bandwidth, the drop in data volume is from 92 to 25MB.
- To add further, a 100ms one-way delay notably reduces performance. This delay is due to request/response delay penalty of HTTP. *These factors play a critical role in determining the performance of a backhaul channel.*
- Another experiment focused the Internet connectivity for large-scale urban scenarios. It was concluded that with a fixed 1Mb/s data rate on the channel, vehicles can gain a median throughput of 20kb/s and a median uploaded data volume of 216Kb.
- The average interconnection and connection establishment time were 75 and 13 sec respectively.
- The experiment yielded a long-term throughput of 86kb/s over the average of interconnection and connection establishment period [13].

4.2 Comparison of Existing Framework with Proposed One [24] [25]

A deeper look into the device specification sheets for the Cisco Kinetic series yields following statistics:

- Cisco kinetics makes use of Cloud security features for delivering services such as data storage, multitenancy and cross platform compatibility within a moderate budget.
- The open architecture enables easier integration of varied services. This platform caters citywide data, thereby permitting usability by a large number of heterogeneous devices.
- The Cisco Kinetic architecture provides complete support for Multitenancy and usability.
- A specialized database at the Fog layer is mandatory to capture recently captured data.
- A great advantage of entertaining device requests locally over the edge is speed and closed-loop supervisory. The data remains within the local loop.
- In case of data being routed to the Cloud, it must be serialized and filtered before being sent northwards.
- Data might need to be timestamped before being sent to the Cloud. It might be needed for time-based analysis. This accuracy is best achieved if the time stamp is recorded as close to the generating device as possible.

In the proposed architecture, the Fog device acts as local data center that stores, processes and analyzes the data. This is the essence of the proposed broker pattern. There are very definite requirements for this data center. These include:

- It must support large, heterogeneous type and volumes of data. It must be fast enough to capture data quickly since the generating devices may not hold data for long.
- It must offer greater flexibility and security than a traditional, relational database management system.

Thus, the requirements are varied and cross functional. A typical case occurs when the fog device needs to collect and aggregate data from multiple nodes. Waiting for the individual device can be cumbersome and time consuming. An alternate solution would be a single query that is geo-distributed. This enables the fog node to propagate a single query across multiple devices, thereby enhancing speed. Moreover, Fog is the best place to ensure data transfer to the Cloud is within the specified format, uniform for all devices and platforms.

4.3 Minimum System Requirements

The minimum system requirements, especially for the Fog devices are as follows:

Hardware: Single core

Disk space: N/A

Memory 256 MB

Software: Ubuntu .Linux red hat etc.

Table below sums up the comparative analysis between the traditional approach and the proposed one.

Table 2: Comparative analysis between two approaches

Attribute	Traditional Approach	Proposed Solution
Device Heterogeneity	Not supported	Fully Supported
Connectivity Time	18-21 sec	5-10 sec
Authentication/Connection Establishment	Significant delay	Insignificant delay due to common authentication database
Backhaul Compatibility	Not observed leading to data drop from 92 to 25MB	Complete backhaul compatibility leading to insignificant data loss
Average Data Transfer rate	86kb/s	In range of multiple GB

V. DISCUSSION AND FUTURE WORK

As already discussed, the alternate architectural pattern approach can greatly facilitate the vision of the fully connected travelling. If enabled and envisioned correctly, fully connected travelling ca n influence the way people travel. It can result in increased productivity and increased citizen satisfaction. A fully connected vehicle, traceable over the internet can serve many purposes. These include automatic update in case of a car accident to the nearest police station, automatic update to the nearest hospital in case of a health emergency or update to workplace in case of traffic jam. Following section describes the few of its major applications.

3.1 Update In Case of a Traffic Accident

In case of a traffic accident the on board unit (OBU) can communicate with the roadside unit (RSU) to indicate the exact time of the accident. Using Cisco Kinetic series, the Data control unit can send this received data to appropriate app using the Edge Fog Module (EFM) [24]. An ideal app to send and receive this data could be *Cisco WebEx Meetings*. The code from design can be generated using Visual studio, C, C# etc. *Cisco WebEx Meetings* is an online meeting app that allows the user to stay online. Details that can be included further may include Driver's Name, Passport number, Emergency contact number and the location of the accident. Furthermore, updates to the local authorities such as nearest hospital and fire stations can be sent. Moreover, a fully connected network could also provide location updates for broadcast. This in turn could enable the incoming traffic to be routed to a diverged path. Thus leading to smarter traffic management and reduced chances of accidents. A more detailed implementation could lead to automatic rerouting to backup/secondary links.

3.2 Update In Case of Health Emergency

In case of a health emergency, similar scenario can be deployed. The connected vehicle is a rich embodiment of sensors and actuators. Apps can be developed that transfer the patient's heart beat and pulse rate to the nearby hospitals. Updates can be sent regarding the possible first aid treatment that can save a person's life. Moreover, the route for the least congestion can be selected for critical emergencies. These enhancements can have a valuable impact on saving a patient's life.

3.3 Update To Workplace In Case of Traffic Jam

Another notable update could be an email sent or an update sent to the workplace in case of traffic congestion. Updates about an employee's current position and relative work arrival time could be calculated too. To add further, the employee could continue utilizing the idle time in managing work from home.

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