Pull-A-Vehicle Approach for Transport with Internet of Things (IoT) based Fleet Management System (FMS)

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Abstract: Logistics and Transportation processes have got a positive impact and a paradigm shift in its operations out of use of technology solutions. Emerging Internet of Things (IoT) provide solutions for the Logistics & Transportation processes. This article explains an IoT based FMS for people and goods transport service provider by integrating passenger in decision-making process and balancing the trade-off of Vehicle Capacity & Wait Time. For this Pull-A-Vehicle Approach has been conceptualized. This paper carries a good study of research literature for gap analysis and concept building. This also provide overview of vehicular communication that creates the basis for research objectives and concept approach of Pull-A-Vehicle.

Key words: Logistics, Transportation, FMS, IoT, IoLT, IoV, Mobility Communication, VANET, ITS

1. INTRODUCTION:

Logistics & Transportation is key to economic development of a society. A good transport system in logistics activities, provide better logistics efficiency, reduce operation cost, and promote service quality (Tseng, 2005). Transportation need for people and goods, result high motorisation, urbanisation and population density, which is resulting in traffic congestion, increasing travel time, fuel consumption and air-pollution (Cowell, 2010). Passenger and freight transport have different challenges. Passenger journeys are decided in terms of origin and destination, mode, timing and frequency of travel by individuals while freight journeys have a single purpose of transporting goods from one point in the supply chain to another (Allen, Browne, & Cherrett, 2012).

A fleet of vehicles is used either for transporting human passengers or containers of goods. However the two have different complexities and challenges. The presence of customer during the passenger journey process itself presents a challenge. To reduce the wait-time for passenger in one hand and at the same time the optimized capacity utilization of vehicles to keep operations viable are trade-offs to be balanced. Therefore a solutions based on Internet of Things (IoT) for good fleet management to realize optimum returns from limited resources is an emerging business opportunity.

1.1 FLEET MANAGEMENT SYSTEMS:

Fleet is a collection of vehicles used in any transport through land, water or air though in this paper it refer to a fleet of vehicles for road transport. Fleet operator is the owner of these vehicles used in any type transport and based on the number of vehicles a fleet operator can be small, mid, large or very large fleet operator. A Fleet Management System (FMS) is an information system to help the fleet operator which is a logistics organizations to operate in efficient & effective manner and realize maximum returns on their investment (Kolaric, 2008). In a competitive environment, technology intervention is a necessity for managing smooth transportation modes and services (Blythe, Rackliff, Holland, & Mageean, 2000). Fleet management include every aspect of the life cycle of a vehicle therefore it is important for companies to employ efficient fleet management systems to reduce risks and increase quality of service in addition to operational efficiency of a fleet at minimal cost (Malekian, Moloisane, Nair, Maharaj, & Chude-Okonkwo, 2017).

1.2 INTERNET OF THINGS (IOT):

The term Internet of Things (IoT) was first used by Kelvin Ashton in 1999 and it has been conceived in parallel to Wireless Sensor Networks (WSNs) (Gawade & Meeankshi, 2017). Through IoT, any physical object referred as thing can be paired with another object, that will enable transmit, receive and process data to and from one object to another (Roberto Minerva, Abyi Biru, 2015) (Li, Xu, & Zhao, 2015). With a smart sensor attached to the object, it get a tiny computer features. And when they do so, they are often called smart things, because they can act smarter than things that have not been tagged (FLEISCH ElgarFleisch, 2010). The new realized capabilities in smart things are of immense value in managing processes. Any process having smart things transmit process status transparently to improve efficiency, performance & effectiveness so that the entire system would become intelligent. In near time the dominance of people-to-people communications will soon be overcome by device-to-device D2D communications (Aloi et al., 2016).

1.3 INTERNET OF LOGISTICS THINGS (IOLT):

The scope for technology is growing in providing innovative solutions for various improvement dimensions of logistics and transportation. Satellite based positioning, ever increasing reach of fast telecommunication and IoT provide more and more technology based solutions. Therefore Barcodes and RFID Tags, which provide control on the basic functionality is now have IoT based solutions covering almost the entire Supply Chain. (Decker et al., 2008). Real-time monitoring and control through smart devices is becoming a necessity in highly competitive environment (Luo et al., 2016).

Logistics and Transportation has been the area which has high impact benefits due to IoT implementations in its processes. The things to be embedded with IoT in this area include vehicles, roads, parking, routes, vehicle hubs, control rooms, satellites and people. With the integration of GPS, GIS and advanced information systems provides a high manoeuvrability of transport systems (Tseng, 2005). The evolving area Intelligent Transport System (ITS) is a part of IoLT and there is a lot of opportunity of business innovation in this area (Blythe et al., 2000), (Coronado Mondragon, Lalwani, Coronado Mondragon, Coronado Mondragon, & Pawar, 2012), (Hasegawa, 2014).

1.4 Internet of Vehicles (IoV) and associated standards for vehicular communication:

IoT with smart sensors network which when added with various communication protocols specific to transport, is emerging into an Internet of Vehicles (IoV) which is to keep drivers updated by informing route, traffic on route, congestion and other information to help in taking decisions. IoV comprises of telematics, vehicle ad-hoc networks, and intelligent transportation (F. Yang, Wang, Li, Liu, & Sun, 2014). Futuristic cellular networks, 5G targets at very high data rates, massive number of devices(IPv6), very low latency and very high reliability to meet the requirements for automated driving and other vehicular applications (Festag, 2015). An integrated effective public transportation of goods and people is a necessity for human and economic development (Anderson et al., 2009). In big cities decentralized residential areas have challenges for private car users, taxis and public transport providers. Frequent car use add to traffic congestion and add to pollution in the environment. Blythe et al., 2000 emphasized that by collecting pre-trip and on-trip information from travellers helps in route plan, mode of travel, traffic congestion, pricing and parking decisions.

Vehicle Ad hoc Networks (VANETS) (Sampigethaya, Huang, Li, Poovendran, Radha Matsuura, & Sezaki, 2005), (J. Wang et al., 2018) is important component of ITS or in any IoV. Vehicular communications (V2X) can be of two types Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications (S. Yang, Wang, & Jiang, 2018).

The vehicular communication protocols are better explained through network layers in below table. These protocols are becoming rich every time and only few has been mentioned here.

Table1: Network Layer Stack for DSRC Protocol

Application Layer	FMS, Vehicle Applications (User interface)	Safety Application (SAE J2735)
Networking Layer	UDP/ TCP	IEEE 1609.2 (Security) IEEE 1609.3
Transport Layer	IPv6	
LLC Layer	IEEE 802.2	
MAC Layer	IEEE 802.11p IEEE 1609.4	
Physical Layer	IEEE 802.11p (WAVE), 4GLTE (1GBPS), Futuristic 5G(10GBPS)	

Source: Adapted from (Bhat, 2018), (Festag, 2015)

2. Literature Review:

Rich literature is available and research is going on in the interesting area of IoLT and ITS. So keeping the research topic study has been done to consolidate the objectives of the paper.

2.1 Vehicular communication standards overview:

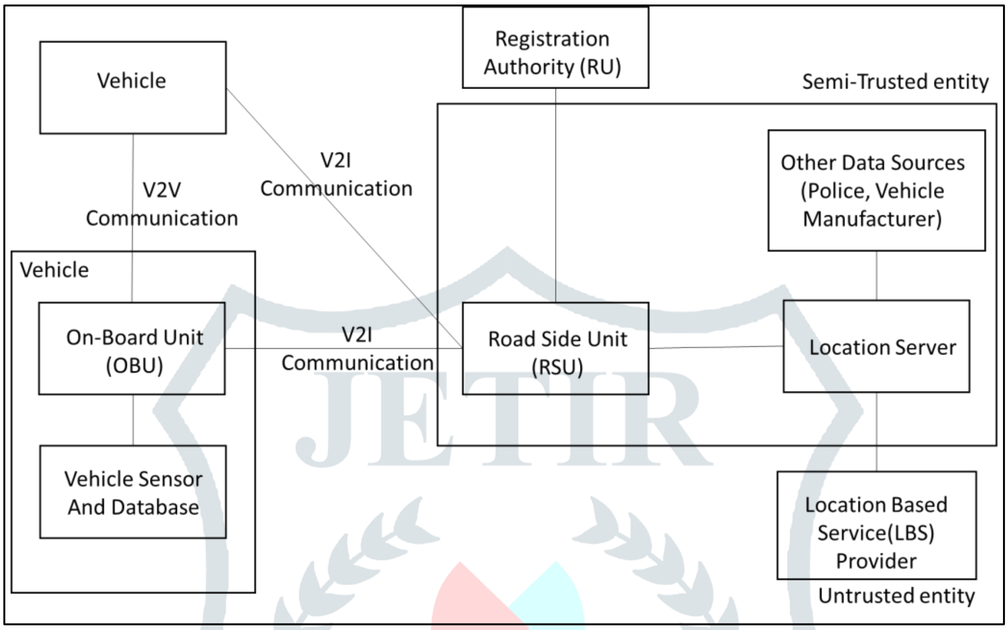
There is sufficient study available which provide a detailed insight on technology used in vehicular communication to enable ITS. When moving vehicles are communicating with nodes making a temporary network which communicates with its surrounding to other vehicles and drivers is called Mobile Ad hoc Networks (MANET) (Martinez, Toh, Cano, Calafate, & Manzoni, 2011). MANET Routing Protocols are useful in alerting drivers to avoid collision and helps them in taking routing decisions by having the idea of vehicles around, road condition ahead, accidents on the lanes. The challenge in managing these networks has been the mobility of vehicles. A framework for systematic analysis of impact of mobility on performance of routing protocols has been suggested with a good insight on MANET routing protocols in a paper by (Bai, Sadagopan, & Helmy, n.d. 2003).

Vehicular Ad hoc Networks (VANETs) is a subclass of MANETs where wireless communication is included (Ho, North, Polak, & Leung, 2010). VANET – Vehicular Ad-hoc Networks has evolved with the advancement of technologies for hardware, software and communication. VANETs with radio enabled vehicles as mobile nodes are key elements for next generation ITS (Liu et al., 2016). The challenges before scientist have always been to provide scalable, secure and reliable solutions. With increasing number of smart phones and computing devices VANET architecture has become very relevant for routing. It has to serve three different networks: Vehicle-to-Vehicle (V2V), Infrastructure-to-Vehicle (I2V) and Vehicle-to-Infrastructure (V2I) (C. Harsch et al. 2007) (S. Zeadally et al. 2010) (Kumar & Dave, 2011) (Cunha et al., 2016). In V2V communication a vehicle is equipped with On—Board Unit (OBU) like GPS (Global Positioning System), APC (Automatic Passenger Counting), AVL (Automatic Vehicle

Location) to enable the vehicle receive an overview and communicate information to another vehicle. Global System for Mobile communication (GSM) and General Packet Radio Service (GPRS) are common wireless data transfer service.

To this the standards like Dedicated Short-Range Communications (DSRC) and Long-Term Evolution (LTE), provides the support to V2X communications (Sampigethaya et al., 2005), (Yao, Wang, Wang, Chen, & Wang, 2018). Scope of ITS, is continuously increasing in FMS to ensure sustainable mobility of goods and people due to urbanization and population. (Tilocca et al., 2017)(Luo et al., 2016) (Osseiran et al., 2014) (Sari, Onursal, & Akkaya, 2015).

Figure1: Components of Vehicular Communication Systems



Source: (Sampigethaya et al., 2005)

2.2 Types of IoT based Fleet Management Systems:

Four types of information and communication systems for logistics and freight transport (Zapata, Arango, & Gomez, 2013)(Perego et al., 2011). Also ever increasing IoT applications and designs reflected from the literature and various feature of these information systems have been listed. Six categories of Intelligent Vehicle Highway Systems (IVHS) as given by Philip E. Agre & Christine A. Harbs (1994) have been adapted in features column.

A good use of technology has been in AVL, Traffic Congestion information, Accident Broadcasts, auto-parking features, collision avoidance system listed on second column of Table2 below. A smartphone based application to facilitate the customer information and to include customer in decision making process like introducing a vehicle would add another application family in the table.

Table2: Types of ITS applications:

Application Family	**Features**
Transportation Management - TM	- Traffic monitoring system - Vehicle tracking system - Navigation system - Pedestrian support system - Commercial vehicle operation system - Weather information system - Vehicle information database
Supply Chain Execution - SCE	- Vehicle Route Planning - Public transport support system

	- Road management & analytics
Field Force Automation - FFA	- Automatic toll collection system - Safe driving support - Safety information and warning system - Traffic signal coordination
Fleet & Freight Management – FFM	- Fleet Size Optimization - Vehicle scheduling - Parking place management - Electronic ticketing and fare collection systems - Traffic management - Emergency vehicle operations support

Source: Adapted from (Zapata, Arango, & Gomez, 2013), (Perego et al., 2011).

2.3 IoT based ITS - FMS applications:

G. Gialis et al. 2004 investigated about the real time vehicle routing VRP in urban distribution management. Their paper gave a framework for use of mobile and wireless connectivity for real time vehicle routing between delivery vehicles and distribution facilities. They propose a system architecture for real-time vehicle management in complex urban scenario. For mobile access GSM (2G) is a matured technology but limited data transmission. GPRS (2.5G) was preferred over GSM in fleet management for high data rate in 2004. Author mentioned TETRA which is a digital mobile radio for point- multipoint radio broadcast. UMTS (3G) in 2004 has been mentioned as emerging standard. Nevertheless VANET are would have impetus from futuristic 5G, wireless LTE, cyber infrastructure and IPv6 protocol standards (Sari et al., 2015).

Anderson et al., 2009 proposed a solution for transportation information system using GSM and SMS infrastructure to message the traveller about the arrival time of a vehicle. An on-board GPS system with GSM modem on a vehicle can communicate location information with central server via Short Messaging Service (SMS) which in turn has algorithm to communicate to travellers about the route and vehicle arrival time (Anderson et al., 2009). The system used a GPS vehicle tracking box installed in a vehicle to track the vehicle. When a route number is sent to control room it locates the vehicle. Now server keep tracking this vehicle from satellite for the change of co-ordinates and change in location. The proposed solution uses a microcontroller to pick the time stamp and location variation and updates one MySQL database with time calculation for various locations. A user through a phone may connect to MySQL database for information of a route number and vehicles there on.

Engelbrecht, Booysen, Bruwer, & van Rooyen, 2015, have given a detailed survey of smartphone based solutions and futuristic ITS development. Driver behaviour analysis predicting a drunk driver behaviour to literature relevant to smartphone sensing in vehicle have been surveyed and revisited. ITS got improved with IEEE 802.11p standard which is p (5.9 GHz) band on Wi-Fi so that vehicles can communicate in its vicinity for V2X communication (Festag, 2015) (Sari et al., 2015).

The Automatic Vehicle Location (AVL) data are used for three on-line transit services: 1-the fleet management and operation, 2-the bus priority at traffic signals, and 3-the real-time passenger information. AVL systems are being used worldwide extensively for efficiency, effectiveness and quality of road transit services (Tilocca et al., 2017).

An android based app has been proposed by (Ahmed, Nada, & Al-Mutiri, 2017) for university bus routing and tracking system. Another prototype has been described by (Gawade & Meeankshi, 2017) for IoT based smart transportation system.

Below in Table3 has a list from the literature review to provide insight, terminology, communication standards, and protocols for managing processes in logistics and transportation systems.

Table3: Summary of IoT enabled logistics and transportation applications.

Author	Transportation Processes (FMS)	IoLT Components & Communication Standards
1. (Blythe et al., 2000)	Toll billing based on road use, smartcard ticketing, vehicle location, on-board	ITS

	information systems in public transport services	
2. (Ernst, Jiang, Krishnamoorthy, & Sier, 2004)	Mobility impact on routing performance and Adhoc networks	MANET
3. (G. Giaglis et al., 2004)	Vehicle routing problem(VRP) and Vehicle routing system(VRS)	Mobile Technologies GSM, GPRS, UTMS. Positioning GPS
4. (Sampigethaya et al., 2005)	Location tracking security aspects like privacy [CARVAN]	-VANET -V2V -V2I
5. (Takatori & Hasegawa, 2006)	Predictive collision warning system	-Sensor devices -Inter-vehicle communication (IVC)
6. C. Harsch et al. (2007)	Position based routing VANET, timestamp and velocity measures.	-GPS -VANET -RSU
7. (Decker et al., 2008)	Quantification of cost model of smart items in supply chain.	-Barcodes -RFID -GSM
8. (Anderson et al., 2009)	SMS, GSM and GPS based transportation information system	Using satellite Mobile tower
9. C. Mulley et al. (2009)	Flexible Transport Services	-Automated vehicle location (AVL) -GSM Network -In-vehicle mobile phone
10. (Ho et al., 2010)	Transport modelling framework	-Link duration -Connected periods -Path duration
11. (Kumar & Dave, 2011)	Routing Protocols	-IEEE802.11p standards -V2V, V2I, I2V -WLAN/ WiMAX
12. (Gascueña & Fernández-Caballero, 2011)	Intelligent surveillance	-CCTV -PTZ Cameras -RFID
13. (Sari et al., 2015)	VANET –OSI Model and architecture	-WiMAX -DSRC -IPv6

14. (Luo H. et al, 2016)	Intelligent tracking system for transportation and monitoring of perishable goods.	-Zigbee wireless telecom protocol -Connected sensors in storage or trucks -Nodes, M2M
15. (X. Wang & Li, 2016)	Urban smart transport based on Cloud, IoT and BigData, speed, and congestion index.	-GIS -4G,WiFi, Bluetooth -Cloud infra for sensor data
16. (S. Yang et al., 2018)	Information exchange at urban road intersection	-ITS -RSU -IEEE 802.11p protocols

3. RESEARCH OBJECTIVE, RATIONALE AND SCOPE:

Three main components in FMS for transport of passenger or freight are customer, infrastructure and vehicles. The scope is to consider passenger transport where passengers would like to travel from one place to another place in a fixed route of urban transport. The requirements of the three components are summarized in below table 4.

Table4: Requirements and scope

Customer	**Infrastructure/ Environment**	**Vehicle/ Fleet owner**
Minimum wait-time: A passenger does not want to wait for a long time.	Infrastructure of vehicle communication including road side units RSU, road itself, communication towers, satellites need be maintained and up for utilization.	Vehicle must run with certain minimum capacity utilization so that fleet owner gets profit from operations.

The present study aims at examining Internet of Things (IoT) enabled Pull-A-Vehicle Fleet Management System based on aggregated demand for a vehicle from passengers searching for a bus to travel from one place to another in fixed routes. FMS helps to manage the optimum utilization of resources which eventually results in the improvement of customer satisfaction and savings from efficient operations. Extensive research literature is available to get insight on the objectives of introducing the fleet management system by a fleet operators. Study of technology and communication is not the scope of the paper and only an introduction which comes from literature review has been mentioned to help understand the proposed approach.

From the literature study, there is not much research which take up the balancing of trade-off measures like wait-time and capacity utilization of a vehicle in transportation of people or goods. Plying a vehicle incurs operations cost which is reimbursed from customers/ travellers from ticketing and pricing. However plying a vehicle with capacity utilization below a threshold level would not be a viable business and therefore there is a rationale in proposing Pull-A-Vehicle Fleet Management System.

The scope of the approach proposed have following objectives.

OB1: In the ambit of IoLT, mining the research papers and list various types of information systems and analyse to various ITS –FMS applications from literature review.

OB2: Gap analysis and list trade-off measures where IoT and technology interference may be useful.
OB3: Propose a Pull-A-Vehicle Approach in place of fixed schedule of a vehicle and list of envisaged components there in the proposed IoT enabled system?

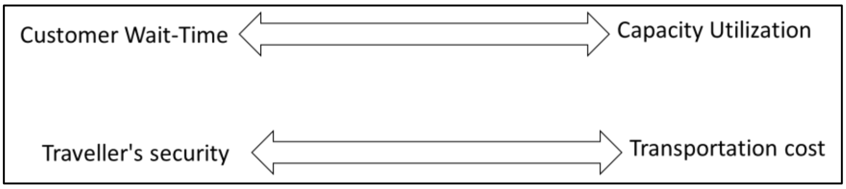
Scope of research paper is a concept proposal in line of the objectives above and not the simulation and further validation of solution.

4. TRADE-OFFS IN FLEET OPERATIONS SYSTEM:

In Pull-A-Vehicle approach is envisaged to balance the trade-off of Minimum Waiting – Time and Maximum capacity utilization of vehicle to realize optimum Cost of Operation. The fleet owner's perspective remain to minimize the operation cost and realize maximum returns and profit.

One very important perspective is traveller's perspective. Traveller is interested for minimum wait-time and safe transport up to destination. These measures are trade off measures to those in fleet owner's perspective as achieving both simultaneously is a challenge. Therefore Transportation Cost and Wait-time is a pair of measures which must be balanced in IoT enabled FMS. And similarly the Traveller security and Transportation cost is another trade-off pair of measures.

Figure2: Pairs of Trade-offs



Source: Self

Traditional approach of fleet operation is Push-A-Vehicle approach where there is periodic pre-defined route schedule being maintained and the technology interference has been in managing transit uncertainty. In traditional approach there are fixed routes and fixed schedule for the vehicle.

5. Proposed Pull-A-Vehicle Approach in fleet operation:

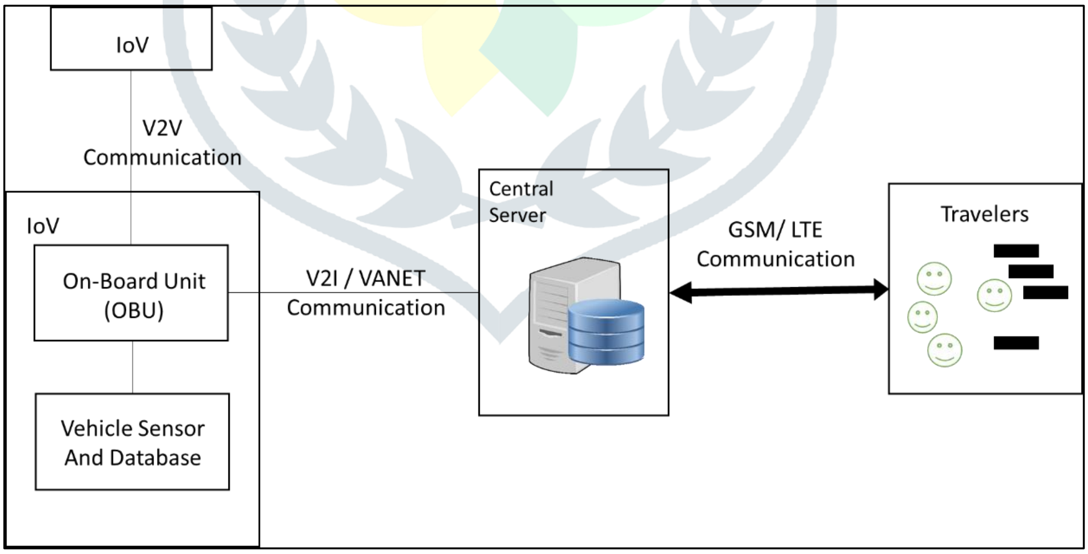
5.1 Traditional approach:

Traditional approach that is observed in most of public transport in urban cities ignores balancing the two trade-off measures like Waiting-Time and Capacity Utilization. The routes are fixed and transport vehicle's schedule is fixed. Like in a city transport a public transport bus stops at defined bus stops for travellers to take a ride and few traveller may get down as their destination bus stop arrive. There may be a high frequency of the transport during peak traffic which is not effective as the traffic peaking is varying and cannot be taken care of by fixed schedule frequency. At the same time the service is not scalable as there is no arrangement if there is a sudden surge of travellers or for some reason there may be very less travellers. For this reason the vehicle carry more passengers than its capacity or it run with under capacity. Both the situation are not favourable neither traveller is satisfied nor the fleet operator is getting optimum returns.

5.2 Components of proposed Pull-A-Vehicle Systems:

Now with IoT enabled fleet management system the travellers or customer is integrated in decision making process. There is no fixed schedule and frequency of transport is taken with the help of an algorithm where the customer response is being aggregated and analysed with the help of IoT enabled FMS.

Figure3: Components of proposed Pull-A-Vehicle Systems



Source: Self

In proposed Pull-A-Vehicle approach, first the demand is aggregated on a route till a desired occupancy level for vehicle is achieved. Algorithm differentiate the passengers who may be served by already plying vehicle on the same route. Traditional approach the schedule for a vehicle and its route is fixed, however in Pull-A-Vehicle approach a vehicle route and schedule is not fixed but vary on the basis of the aggregated demand on a central server. And if demand is high enough on a route than even more than one vehicle can be deputed on service. A mobile application provide a dashboard to a traveller to connect to central server and avail the information pertaining to transportation on the route he wish to travel.

5.3 Assumptions:

The key decision of assigning vehicle on a route and aggregate the demand is based on following assumptions.

1. The proposed concept is for single logistic service provider for transport like urban city public transport service. The service provider has sufficient fleet size to realize scalability.
2. Vehicles in fleet are fully equipped with IoLT to realize IoV environment using vehicular communication.
3. Central Control Room has infrastructure for communication and computing facility, with connectivity to IoV and access to travellers through a mobile application running on smart phones.

5.4 Mathematical illustration for Pull-A-Vehicle approach:

Assume P_{ijkl} represent a passengers on a route number Ri at certain time Tj who have to pick transport at K stoppage and his destination is L stoppage.

The passenger enquired for the vehicle demand through his smartphone/web application to server.

Ri = Fixed Route Number (i = 1, 2, 3……….n)

Tj = Timestamp of enquiry logging.

K = Boarding stoppage on the route

L = Destination stoppage on the route

$\therefore P_{ijkl}$ ………………………………………………………………… (1)

Similarly, V_{abcd} represent a vehicle plying on Route number Ra at time Tb and at the moment the vehicle is approaching stoppage C and last stoppage for vehicle is D.

Ra = Fixed Route Number (a = 1, 2, 3……….n)

Tb = Timestamp from latest status of vehicle.

C = Approaching stoppage for vehicle.

D = Last stoppage for the vehicle

$\therefore V_{abcd}$ ………………………………………………………………… (2)

As the vehicle is moving the approaching stoppage keep changing for the vehicle and status is updated through AVL that can be monitored from control room.

A counter variable Cx is set in such a way that it is incremented or reset through algorithm on the event of every logged request on server.

In the event of new request the algorithm looks for the route number and boarding stoppage from request and from vehicle if any which might be approaching the stoppage on the same route.

Case:

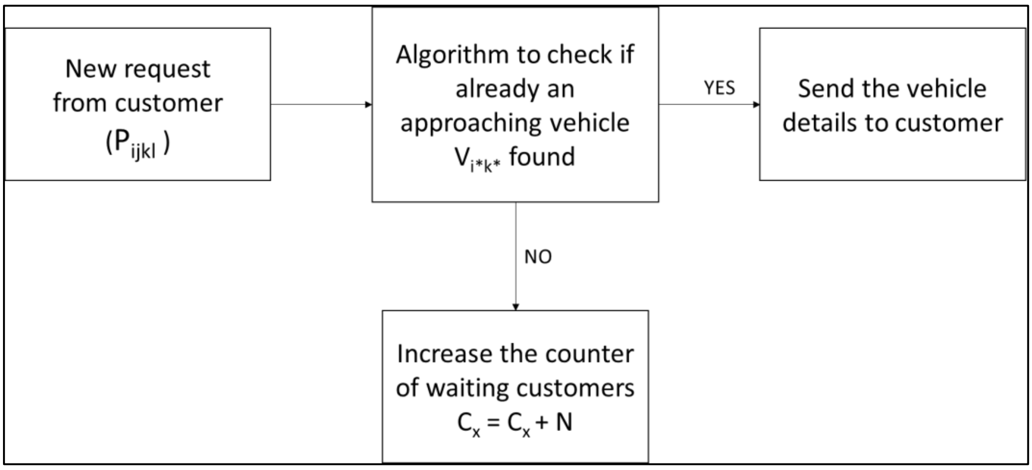
Already vehicle is plying then send the vehicle detail

Else:

Cx = Cx + N (N=Number of travellers together)…… (3)

This measure Cx should be greater than a pre-defined number (Ct) to trigger a new vehicle be put on service.

Figure3: Pull-A-Vehicle Systems



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5.5 BENEFITS OF PULL-A-VEHICLE APPROACH:

1. The proposed approach ensures that there is always either a vehicle which would be already plying or the status as how many travellers are waiting.
2. The proposal would help ensure a good capacity utilization so that fleet operator is benefitted. At the same time a passenger waiting is in loop and his waiting time is approximated easily can be incorporated on the message he received.
3. This is a scalable service, provided the sufficient fleet size is maintained.
4. This approach helps balancing the trade-offs of Waiting time & capacity utilization.
5. More complex transport meant for passengers may be replicated easily for goods transport.

6. CONCLUSION:

Pull-A-Vehicle approach will be effective by integrating customer with the system for decision making and information sharing that would provide better service and customer satisfaction. The system would ensure optimized transportation cost as the capacity utilization is maximized by aggregating the demand and is scalable if realized. This paper highlight the trade-off measures of Transportation-Cost and Wait-Time and proposed a shift from traditional approach with IoT-FMS based Pull-A-Vehicle approach. Research paper provide theoretical basis through literature review and provide the insight for vehicular communication and futuristic ITS.

The conceptual approach can be further investigated through simulation for which mathematical illustration of approach is explained. Research may further require a validation. Such system would provide useful data which with analytics capabilities, can be useful in futuristic product design, and more robust solutions.

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