Moving From Vehicular Cloud Computing to Vehicular Fog Computing:Issues and Challenges

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***Abstract*— Vehicular Ad Hoc Networks (VANETs) are specific types of Mobile Ad Hoc Networks (MANETs) in which the mobile nodes are moving vehicles. The vehicles consist of on-board units and a group of sensors to gather data and to communicate with the other vehicles and the roadside units (RSUs). VANETs have received increased attention in recent years due to its numerous applications in surveillance services, emergency situations, route planning and traffic alert broadcasting. VANETs have been depending on cloud computing services for networking, computing and data storage. With the emergence of advanced vehicular applications, the demands for powerful communication and computation facilities with low latency and uninterrupted services have been increasing. With cloud computing unable to satisfy these demands, the focus has shifted to bring computation and communication facilities nearer to the vehicle and even utilizing vehicles as infrastructures, leading to the emergence of Vehicular Fog Computing (VFC). VFC utilizes vehicles as infrastructures for communication and computation and also installs highly virtualized computing, communication and storage facilities at the proximity of these vehicles. This implementation of VFC comes with a number of issues and open problems. This study provides insights into this latest promising technology of Vehicular Fog Computing and discusses issues and challenges in its implementation with future trends in this domain.**

Keywords- Ad Hoc Networks, Challenges, Cloud Computing, Fog Computing, Issues, VANETs, Vehicular Fog Computing

I. INTRODUCTION

A Mobile Ad Hoc Network (MANET) [1-6] is a collection of wireless devices like mobile phones, laptops and iPads that can dynamically form a wireless network for communication in emergency situations, disaster recovery operations [7-9] battlefields etc. These networks are deployed without the support of any fixed infrastructure like access points or a centralized control. It is an autonomous system of mobile devices that enables each device to join or leave the network at any time leading to a highly dynamic and unpredictable topology. A Vehicular Ad Hoc Network [10-12] is a specific type of MANET in which the mobile nodes are moving vehicles. In VANETs every vehicle is equipped with an on-board unit and a group of sensors. This radio interfaces or on-board unit enables short range wireless ad hoc networks to be formed. VANETs offer both vehicle to vehicle and vehicle to roadside communication [13-14]. Every vehicle in the network plays the role of a sender, receiver and a router to broadcast data to the vehicular network and the roadside units which then uses the data to ensure safe and free flow of traffic. VANETs are used in the design and development of Intelligent Transportation Systems (ITS) which offers improved safety and better transportation. VANETs are currently being used for traffic monitoring, emergency services, safe driving, infotainment services, location detection services, automated toll payment etc.

VANETs have been depending primarily on cloud computing [15-16] services for communication, computing and storage facilities. Cloud computing offers computation and storage facilities using a central cloud server or a group of remote servers. Cloud computing provides users with scalable virtual networks, virtual servers for remote storage space and computing facilities. Data stored can be accessed from any place without the trouble of keeping large storage and computing devices in the vehicles. Users could share and distribute large amount of data between the vehicles. One of the major areas of concern in cloud computing is the delay in transfer of data and information from the vehicles to the remote cloud server and back to the vehicles after storage and processing. With tremendous rise in the number of connected vehicles and with their ever increasing mobility, the demand for applications that support low latency, uninterrupted services is rising day by day. It has become quite difficult to meet the challenges of efficient communication and computation with the emergence of latest and advanced vehicular applications. Providing required Quality of Service (QoS) is another important challenge faced by Vehicular Cloud Computing (VCC) [17-21] services that integrates cloud computing with VANETs. Various vehicular applications designed for latest high speed vehicles will require powerful communication and computational support. Apart from cloud computing, the other solutions used to provide communication and computational support was Fourth Generation Cellular Networks [22] and Road Side Units [23]. However these technologies suffered from many limitations. Cellular networks were controlled by their respective service providers, thus limiting the flexibility in communication in VANETs [22]. There are many difficulties in deploying Road Side Units at a larger scale and also incurs high cost [23].

Fog computing is a paradigm that extends cloud computing services to the edge of the network [24-26] It introduces an intermediate fog layer between the cloud and the mobile devices. Devices with computing and communication capabilities (fog nodes) are deployed in this fog layer near to the user devices. As computing and storage facilities are provided on the edge (very near to the user), applications offers better QoS with fog computing. Extending fog computing to vehicular networks (Vehicular Fog Computing) [27] helps to provide powerful communication and computational support to the latest applications in vehicular networks. This article presents an overview of fog computing in VANETs and discusses the latest issues and challenges existing in Vehicular Fog Computing (VFC).

II. VEHICULAR CLOUD COMPUTING

With cloud computing services, users could easily rent infrastructure and even software's that are needed to run their applications. Cloud computing technology thus saved the users from the cost of investment on infrastructure. The most important advantage of cloud computing was its scalable access to computing resources. With increased demand for communication and computing applications in vehicular networks, cloud computing technology was integrated to vehicular networks to form Vehicular Cloud Computing (VCC). Cloud computing provides Network as a Service and Storage as a Service to the vehicles in the network. Cloud computing deploys remote cloud servers in various locations that handle data storage and processing. The data gathered by the sensors in the vehicles has to reach these remote cloud servers through the network for storage and processing. The number of connected vehicles in the network has increased exponentially in recent years along with dynamic mobility. Applications have started to demand better Quality of Service in VANETs and thus Vehicular Cloud Computing is faced with a number of limitations. The major limitations faced by Vehicular Cloud Computing is summarized as,

- Delay in real time responses: The back-and-forth traffic between cloud servers and devices in vehicles leads to increased delay in processing and response to messages.
- Increased mobility of users: Cloud servers are finding it hard to process the billions of service requests from highly mobile vehicles.
- High wireless bandwidth cost: Constant communication between the vehicle and the cloud server requires high bandwidth. This heavy traffic also causes drainage of energy in many wireless devices.

III. VEHICULAR FOG COMPUTING

Fog computing provides a virtual platform for local computing, storage and processing in end user devices rather than in centralized data servers. Fog computing deploys a network of fog servers between the underlying networks and the clouds. In Vehicular Fog Computing the computing, communication and storage services are provided at near user edge devices. A fog server layer is deployed between the vehicles and the cloud server. End users and vehicles are also considered part of the "fog". In contrast to the cloud computing services which are more centralized, fog computing targets applications with widely distributed deployments. The sensors and other devices in the vehicles gather data and this data is stored and processed in intermediate fog servers. Thus the services provide low-latency communication and more context awareness. Figure 1 shows architecture of Vehicular Fog Computing. Most of the data from the vehicles are processed at the fog servers and immediate response is provided to the vehicles. Communication from the fog layer to the cloud server takes place only when required. Fog computing is highly beneficial for low latency applications such as video streaming and gaming.

Table 1 shows the comparison of Vehicular Fog Computing (VFC) with Vehicular Cloud Computing (VCC). Communication delay is low in VFC compared to VCC. While VFC offers high support for mobility, VCC only supports applications that are less mobile. Vehicular Cloud Computing is bandwidth constraint with high cost of deployment. Vehicular Fog Computing on the other hand has low cost of deployment with real time load balancing and local decision making

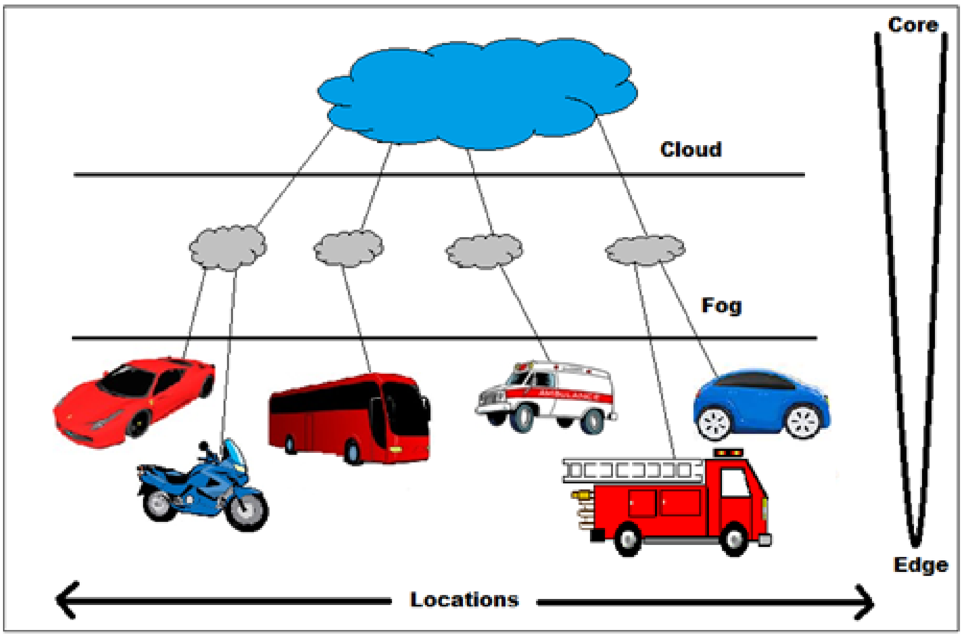

Figure 1: Vehicular Fog Computing

Table 1. Vehicular Fog Computing vs. Vehicular Cloud Computing

Computing Type / **Features**	Vehicular Fog Computing	Vehicular Cloud Computing
Location of computing, communication and storage facilities	At the proximity of users	Remote locations away from the users
Latency of real time applications	Low	High
Mobility support	High mobility support	Limited mobility support
Decision making	Local	Remote
Communication	Real Time Load Balancing	Constraints in Bandwidth
Storage	Limited storage space	Highly scalable storage space
Computing Capabilities	Medium Computing Capabilities	Higher Computing Capabilities
Cost of Deployment	Low	High

Advantages of Vehicular Fog Computing

- **Low latency**: Real time processing of data takes place on the edge, much closer to the vehicle. This provides faster results which can be send as messages to other vehicles and road side units.
- **Pooling of local resources**: Idle processing power and sensing ability within the devices at the edge can be pooled for better services in a fog network.
- **Better Quality of Service**: With fog computing, applications can offer much faster data rates with minimum latency and response time.
- **Improved efficiency of network**: Fog computing avoids the back-and-forth traffic between cloud servers and devices in vehicles. This saves the bandwidth in the network.
- **Reduced energy consumption**: Reduced traffic in the backbone network helps to conserve energy in the devices. Energy conservation in devices with limited battery support is a very important advantage of fog computing.
- **Improved agility of services**: Fog computing fosters rapid innovation and affordable scaling. Instead of waiting for changes to be made to the cloud servers and services, users can customize new applications that are available much nearer to them.

IV. ISSUES AND CHALLENGES

Most of the latest applications in vehicular networks require powerful computational and communication support for efficient functioning. Many applications such as gaming, video streaming etc. always demand low latency communication. These demands are met by deploying fog servers near to the vehicles. But extending fog computing into vehicular ad hoc networks have led to a number of open issues and challenges. We present and discuss these challenges and open problems in Vehicular Fog Computing. Many advanced applications could be designed for vehicles with this very latest and powerful technology.

A. Quality of Service

Quality of Service is one of the most important performance parameter for any communication network. With application users demanding better Quality of Service, it's vital for Vehicular Fog Computing to satisfy the demands. We focus on transmission delay and reliability as the two important Quality of Service parameters for VFC networks [28]. With highly mobile vehicles, the topology of VANETs remains dynamic throughout. So it's very important to design a routing mechanism that would ensure minimum delay in communication between the vehicles and the fog nodes. Also the delay caused by route failures and retransmissions has to be minimized. The routing mechanism has to take care of the fog nodes deployed near to the users. These devices might be manufactured by different vendors with limitations in mobility and power. The routing mechanism must be supported by the fog nodes and also by the sensors in the vehicles. The fog nodes and the fog computing platform must be able to provide 24*7 support to the application users. Reliability of communication is another major area of concern in VFC. The communication framework should be designed to maintain continuous and reliable communication between the vehicles and fog nodes. With the distributed framework of VFC, it's highly challenging to detect and repair the fog nodes. VFC need to address the major issues in reliability that includes detection of transmission failures, rescheduling failed tasks and recovering from failures in the system.

B. Resource Management

Efficient utilization of available computation and storage resources in vehicles is a major area of research in VFC. Many techniques used for resource sharing in ad hoc networks [29-30] is being tried and tested in VFC. A set of protocols or agreements have to be designed for efficient resource sharing between the vehicles. VFC must make sure that every connected vehicle in the network authorizes the transfer of messages and sharing of resources with one other. A number of efficient protocols have to be devised to detect the idle resources in vehicles and the distribution of tasks among the vehicles. This is an area very less explored by researchers.

C. Vehicular Mobility Models

Prediction and analysis of vehicular movements are very important factors in designing routing protocols and resource management mechanisms in VFC. With tremendous rise in the number of connected vehicles and with their ever increasing mobility, it has been very difficult to arrive at a near accurate mobility model. Many mobility models [31-32] have been suggested for VFC. But a much accurate mobility model is required to design efficient applications in VFC. Accurate knowledge of vehicular mobility patterns will help in designing efficient routing protocols for communication and computation in VFC. With precise mobility models it's easier to design the right protocols for communication and resource sharing.

D. Security and Privacy

To date, very few works have been done on security and privacy issues in vehicular fog computing. With large amount of resources and data being shared in the network, it's important to have stringent and clear security mechanisms in VFC. Lack of proper authentication mechanism can lead to security attacks in the network. With information transmitted between the vehicles being used for safe driving and traffic monitoring, any tampering on data can be fatal. The network has to be protected from misuse of information, resources and protocols by intruders. Considering the sensitivity of user data being distributed in such a dynamic network, it's important to ensure data integrity and privacy. Privacy protection and data confidentiality in VFC is an area very less studied.

V. CONCLUSIONS

In this article we have presented an overview of deploying fog computing in vehicular networks which is a new paradigm referred as Vehicular Fog Computing. Initially we discussed about vehicular cloud computing and its limitations in supporting advanced applications for highly mobile vehicles in vehicular ad hoc networks. With increasing number of connected vehicles, and continuously increasing mobility, vehicular cloud computing suffers from certain restrictions. We discussed the new opportunities and possibilities brought in by fog computing in these highly dynamic vehicular networks. We discussed the deployment of fog layer between the vehicles and the cloud servers. We highlighted and discussed the advantages of Vehicular Fog Computing over Vehicular clod computing. VFC provides user applications with high mobility support and low latency communication.VFC also has low cost of deployment with real time load balancing and local decision making. Finally we discussed the issues and challenges that arises with Vehicular Fog Computing and provided future research directions.

REFERENCES

[1] Chlamtac, I., Conti, M., & Liu, J. (2003). Mobile ad hoc networking: imperatives and challenges. Ad Hoc Networks, 1(1), 13-64. http://dx.doi.org/10.1016/s1570-8705(03)00013-1.

[2] Conti, M. & Giordano, S. (2014). Mobile ad hoc networking: milestones, challenges, and new research directions. IEEE Communications Magazine, 52(1), 85-96. http://dx.doi.org/10.1109/mcom.2014.6710069.

[3] Varun G Menon and Joe Prathap P M (2016). Routing in Highly Dynamic Ad Hoc Networks: Issues and Challenges. International Journal of Computer Science and Engineering. vol.8, no. 4, pp.112-116, 2016.

[4] Varun G Menon, Sreekala C S, Vibin J, Teenu T. ,Eldho A (2013). Performance Analysis of Traditional Topology based Routing Protocols in Mobile Ad hoc Networks. The International Journal of Computer Science Applications,vol. 2,no.1, pp. 1-6.

[5] Varun G Menon and Joe Prathap P M (2016). Performance of various Routing Protocols in Mobile A Hoc Networks-A Survey. Research Journal of Applied Sciences, Engineering and Technology, 6(22), pp. 4181-4185.

[6] Varun G Menon, Jogi Priya P M, Joe Prathap P M. (2016). Analyzing the behavior and performance of greedy perimeter stateless routing protocol in highly dynamic mobile ad hoc networks. Life Science Journal , 10(2): pp 1601-1605.

[7] Menon, V., Pathrose, J., & Priya, J. (2016). Ensuring Reliable Communication in Disaster Recovery Operations with Reliable Routing Technique. Mobile Information Systems, 2016, 1-10. http://dx.doi.org/10.1155/2016/9141329

[8] Varun G Menon and Joe Prathap P.M. (2016). Analysing the Behaviour and Performance of Opportunistic Routing Protocols in Highly Mobile Wireless Ad Hoc Networks. International Journal of Engineering and Technology, vol. 8, no. 5, pp. 1916-1924.

[9] V. G. Menon and P. M. Joe Prathap. (2016) Opportunistic routing with virtual coordinates to handle communication voids in mobile ad hoc networks. in Advances in Signal Processing and Intelligent Recognition Systems, vol. 425 of Advances in Intelligent Systems and Computing, pp. 323–334, Springer International.

[10] Kiess, W. & Mauve, M. (2007). A survey on real-world implementations of mobile ad-hoc networks. Ad Hoc Networks, 5(3), 324-339. http://dx.doi.org/10.1016/j.adhoc.2005.12.003

[11] Li, F. & Wang, Y. (2007). Routing in vehicular ad hoc networks: A survey. IEEE Vehicular Technology Magazine, 2(2), 12-22. http://dx.doi.org/10.1109/mvt.2007.912927

[12] Dua, A., Kumar, N., & Bawa, S. (2014). A systematic review on routing protocols for Vehicular Ad Hoc Networks. Vehicular Communications, 1(1), 33-52. http://dx.doi.org/10.1016/j.vehcom.2014.01.001

[13] Chen, R., Zhong, Z., Chang, C., Ai, B., & He, R. (2015). Performance analysis on network connectivity for vehicular ad hoc networks. International Journal Of Ad Hoc And Ubiquitous Computing, 20(2), 67. http://dx.doi.org/10.1504/ijahuc.2015.071692

[14] C. Harsch, A. Festag and P. Papadimitratos, (2007). Secure position-based routing for VANETs. 2007 IEEE 66th Vehicular Technology Conference, Baltimore, MD, pp. 26-30.

[15] Vouk, M. (2008). Cloud Computing-Issues, Research and Implementations. Journal Of Computing And Information Technology, 16(4), 235. http://dx.doi.org/10.2498/cit.1001391

[16] Rountree, D. & Castrillo, I. (2014). Basics of cloud computing (1st ed.). Amsterdam: Elsevier Syngress.

[17] Olariu, S., Khalil, I., & Abuelela, M. (2011). Taking VANET to the clouds. International Journal Of Pervasive Computing And Communications, 7(1), 7-21. http://dx.doi.org/10.1108/17427371111123577.

[18] Shojafar, M., Cordeschi, N., & Baccarelli, E. (2016). Energy-efficient Adaptive Resource Management for Real-time Vehicular Cloud Services. IEEE Transactions On Cloud Computing, 1-1. http://dx.doi.org/10.1109/tcc.2016.2551747

[19] Whaiduzzaman, M., Sookhak, M., Gani, A. and Buyya R.(2014). A survey on vehicular cloud computing. Journal of Network and Computer Applications, vol. 40, pp. 325–344.

[20] Vaquero, L. & Rodero-Merino, L. (2014). Finding your Way in the Fog. ACM SIGCOMM Computer Communication Review, 44(5), 27-32. http://dx.doi.org/10.1145/2677046.2677052

[21] Mekki, T., Jabri, I., Rachedi, A., & Jemaa, M. (2016). Vehicular cloud networks: Challenges, architectures, and future directions. Vehicular Communications. http://dx.doi.org/10.1016/j.vehcom.2016.11.009

[22] G. Hampel, K. L. Clarkson, J. D. Hobby, and P. A. Polakos, “The tradeoff between coverage and capacity in dynamic optimization of 3G cellular networks,” in Proc. VTC—Fall, Orlando, FL, USA, Oct. 4–9, 2003, pp. 927–932.

[23] W. Kuo, Y. Tung, and S. Fang, “A node management scheme for R2V connections in RSU-supported Vehicular ad-hoc networks,” in Proc. ICNC, San Diego, CA, USA, Jan. 28–31, 2013, pp. 768–772.

[24] Chiang, M. & Zhang, T. (2016). Fog and IoT: An Overview of Research Opportunities. IEEE Internet Of Things Journal, 1-1. http://dx.doi.org/10.1109/jiot.2016.2584538

[25] Dastjerdi, A. & Buyya, R. (2016). Fog Computing: Helping the Internet of Things Realize Its Potential. Computer, 49(8), 112-116. http://dx.doi.org/10.1109/mc.2016.245

[26] Bonomi, F., Milito, R., Zhu, J. and Addepalli, S. (2012). Fog Computing and Its Role in the Internet of Things. Proceedings of ACM Mobile cloud computing (MCC '12), New York, NY, USA, pp. 13-16.

[27] Hou, X., Li, Y., Chen, M., Wu, D., Jin, D., & Chen, S. (2016). Vehicular Fog Computing: A Viewpoint of Vehicles as the Infrastructures. IEEE Transactions On Vehicular Technology, 65(6), 3860-3873. http://dx.doi.org/10.1109/tvt.2016.2532863.

[28] Yi S., Li C. and Li Q. (2015). A survey of fog computing: concepts, applications and issues. Proceedings of the 2015 Workshop on Mobile Big Data (MoBiData’15), ACM, New York, NY, USA, pp. 37−42.

[29] Buttyan L. and Hubaux, J. P. (2000). Enforcing service availability in mobile ad-hoc WANs. Mobile and Ad Hoc Networking and Computing, (MobiHOC-2000) First Annual Workshop on, Boston, MA, pp. 87-96.

[30] Zhong, S., Chen J. and Yang, Y. R. (2003). Sprite: a simple, cheat-proof, credit-based system for mobile ad-hoc networks. INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies, vol.3, pp. 1987-1997.

[31] D. Naboulsi and M. Fiore, “On the instantaneous topology of a large-scale urban vehicular network: The Cologne case,” in Proc. ACM MobiHoc, Bangalore, India, Jul. 29–Aug. 1, 2013, pp. 167–176.

[32] W. Viriyasitavat, O. K. Tonguz, and F. Bai, “Network connectivity of VANETs in urban areas,” in Proc. IEEE SECON, Rome, Italy, Jun. 22–26, 2009, pp. 1–9.