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A Review of Interoperability issues in Internet of Vehicles (IoV)

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Abstract: Internet of Vehicles (IoV) is the new era of Internet of Things that interfaces the vehicles to the things through various communication modules to send and receive the data. In-spite of several benefits, IoV faces many technical challenges. Interoperability is the ability of systems to communicate with each other. Sensors/devices embedded in vehicles made up of different manufacturers speak different language. In a situation, where two vehicles communicate with each other to alert about road conditions to ensure safe driving and avoid hazards. It becomes mandatory to ensure both vehicles would exchange and interpret the information correctly, otherwise this could even put the lives at risk. One key aspect that's particularly tended to in this paper is issues of interoperability in IoV. Also, this paper addresses the current state of Interoperability and possible attempts to interoperability solutions in the field of IoV.

Keywords: Interoperability , Middle Ware , Internet of Vehicle

1. Introduction

As defined in [1] [2] [3] [4], IoT is a network of billions and billions of devices which has the ability to exchange the data, remotely monitoring and controlling the data. Whereas, it is defined simply in [5] as more objects connected to the internet than people. As estimated in [6], by 2020 there will be more than 30 billion devices connected to the internet by everyday objects. Figure 1 shows the roadmap of IoT from the existing to predicting the future. Internet of Things (IoT), an advanced technology which is growing expeditiously because of its tremendous features and potential to run the world. IoT has spread its applications across all sectors that includes both public and private. Some of the applications include engineering, industry, infrastructure, government, safety, home, office, health and medicine. other applications include environmental monitoring, energy, and transportation etc. Figure 2 summarizes IoT applications in a broad sense. Some of the features that has famed IoT are flexibility, adaptability, sensing, data collection, automation and networking. Further, IoT has the ability to make the things "smart" which is technically termed as "artificial intelligence". it has the ability to make the things "connected" through existing technologies. it enables the things to actively engage with connected technologies which is technically termed as "active engagement". however, active engagement is only possible through the reach of Sensors. Sensors are the back bone of IoT since it is considered as one of the most important hardware in IoT systems. IoT unlocks several technological pitfalls. Because of its stupendous features, IoT has spanned its advantages across every industries. Some of the advantages of IoT include active engagement since the data analytics in the market lacks with accuracy and hence bounded with passive engagement, optimized technology, effective management of resources and accurate data collection. To deal with data collection, data integration, IoT software's are in use .Several standard protocols and networking technologies have been exploited and many enabling technologies have been developed for IoT. One of the major challenge in data collection is to get right data with high accuracy. However, IoT faces several challenges and barriers in the real world. Some of them include security, privacy, complexity and standardization. Transportation plays a crucial role in smart cities by ensuring smooth traffic flow and reducing accidents to atmost minimum by developing proper communication and information technologies. Components of smart city are smart manufacturing, smart government, mobility/wifi, smart health, smart farming and smart transportation

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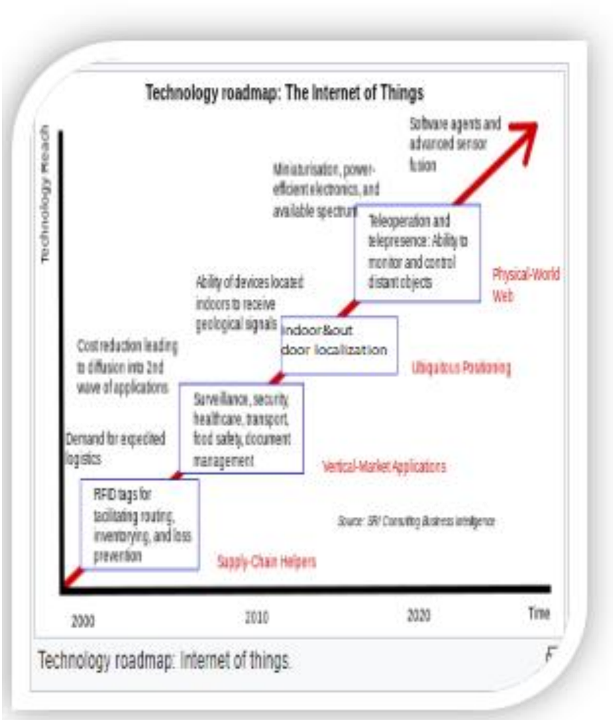

Figure 1. Technology Roadmap: Internet of Things [7]

From the above figure, one can easily notice that how IoT is shaping the technology with the daily usable objects and how the advancements growing rapidly to make the life's of human simpler and easier. However, besides advancements in IoT and due to increase in connectivity among physical devices could raise bigger issues that is needed to be addressed to develop better solutions which is a major challenge for researchers.

TABLE 1 IoT Applications [8]

1	IoT Smart Home	includes applications such as automated switching of Lights , monitoring power consumption on monthly basis ,
2	IoT Wearable's	IoT wearable's mainly include watches , lockets to collect the information about the user such as health , fitness etc.
3	IoT Connected Cars	Includes exchanging information about road conditions, accidents to neighboring vehicles for taking preventive measures.
4	IoT Industry	It includes tracking information about goods, information exchange among suppliers and retailers.
5	IoT Smart Cities	One of the powerful application of IoT. Solving major problems of cities that includes traffic issues , road accidents , parking etc.
6	IoT Agriculture	Collecting information about soil moisture Levels , water utility for plants etc.
7	IoT Smart Retail	Providing better services to the consumers even though they are out of store
8	IoT Energy Management	Data collection about power consumption to improve efficiency
9	IoT Health Care	Includes collecting data about wellbeing of a person
10	IoT Poultry and Farming	Includes animal health monitoring , data collection about animals health to take preventive measures and hence improving poultry production

IoT finds numerous applications in all sectors as discussed in Table 1. Sensors and actuators are the basic IoT hardware components that are used for data collection and information exchange. However, the communication between IoT devices is wireless, there is a need of reliability and distortion less communication. Hence communication technologies plays a very vital role in IoT [9]. Another important challenge in IoT is to deal with heterogeneous environments. Hence, this brings a major challenge to deal with heterogeneous components. As mentioned in [9] , middle ware is used to manage communication among heterogeneous components. Still, standardization remains a big challenge. In the recent years, various architectures have been proposed by researchers since IoT architecture is not agreed globally. Some of the architectures as discussed by authors in [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] are three layer architecture, five layer architectures, fog and cloud architectures. All these architectures are summarized in Table 2. However, these distributed architectures could raise a research question. what would be the right architecture for IoT? Are these architectures confined to a specific applications in IoT? if everyone has their own architecture deployed. How one can guarantee to achieve design goals such as privacy, security, intelligence, cost, mobility, efficiency and quality of service etc.

TABLE 2. Summary of IoT Architectures

1	Three Layer Architecture	Application layer , network layer , perception layer	These three layers are not sufficient for IOT research
2	Five Layer Architecture	In addition to three layer architecture two more layers have been added – transport and processing layer	one of the major identified layer in this architecture is middle ware layer to provide better solutions to interoperability issue
3	Fog Architecture	security , storage , preprocessing and monitoring layer is added	performs data analytics and data processing
4	Cloud Architecture	It includes devices , gate ways , cloud service and mobile [21]	computing is done in centralized fashion

2. Autonomous/Automated Vehicles (AV) to Internet of Vehicles (IoT - IoV)

Experiments have started since 1920's to develop automated vehicles and the first ever automated car "tsukuba automated car" came into existence with two cameras installed on it [22]. Soon after years, autonomous cars came into existence in 1980's. The difference between the words "Autonomous and Automated "are autonomous means self-governing whereas automated means automatic relying on artificial support [23]. Automated cars were classified into six different levels from Level 0 to Level 5 i.e. fully manual to fully automated systems. Though automated vehicles have been developed to strive transportation world, it faces several obstacles and disadvantages which needs to be addressed and find solutions to make the transportation system efficient. Table 3 summarizes advantages of automated vehicles (AV), whereas Table 4 summarizes limitations of automated vehicles (AV) and Table 5 summarizes its disadvantages

TABLE 3. Summary on Automated Vehicles Advantages

S.NO	ADVANTAGES	REMARKS
1	Safety driving	development of driverless cars (Fully automated system) could substantially reduce the road disasters mainly caused due to the driver carelessness [24] [25] [26] [27]
2	Reduces Labor cost	Fully automated cars does not require human intervention there by reducing labor cost
3	Reduces traffic related problems	traffic congestion problems can be reduced
4	Low cost	Improved fuel efficiency due to reduced traffic congestion and smooth traffic flow

despite of numerous advantages, autonomous cars faces potential limitations as shown in Table 4

TABLE 4. Summary on Automated vehicles limitations

S.NO	LIMITATIONS	REMARKS
1	Sensitive to weather conditions	vehicles susceptibility to various weather conditions such as jamming , interference and spoofing [28]
2	Tracking and navigation	It is found that the autonomous vehicles are ineffective to some of the vehicles such as kangaroos [29]
3	Optimization with road infrastructure	for the autonomous cars to function properly , The road infrastructure should be optimize [30]
4	Field programmability	The frameworks will require cautious assessments of item advancements and the supply chain [31] [32] [33]
5	Customized maps	Autonomous cars would require specialized maps to update for any changes in the road infrastructures [34]

A widespread adoption of autonomous vehicles could lead to several disadvantages which are summarized below in Table 5

TABLE 5 Summary on Automated Vehicles Disadvantages

S.NO	DISADVANTAGES	REMARKS
1	Privacy and security	one major issue is hacking since the information is relayed to other vehicles and infrastructures [35]
2	Job losses	Adoption of autonomous vehicles could lead to huge job losses [36]
3	Productive and more efficient software development	Two major requirements in software development is efficiency and productivity. that is the self-decision

		making capabilities of autonomous cars which has raised a big question to programmers to minimize road disasters and save people lives [37]

In recent years, some of the automated vehicles that involved in incidents are listed below in Table 6. This shows that many of the research advancements is still left.

TABLE 6 Summary on Automated Vehicles incidents

S.NO	AUTOMATED VEHICLE	REMARKS
1	Navya automated bus	The automated bus involved in a crash on nov 9 2017 in Las Vegas [38]
2	Uber – automated vehicle	incident took place on march 18 2018 and killed one person [39] [40]
3	Google self-driving car	in 2016, cars software crashed [41].
4	Tesla autopilot	in 2016 and 2018 , many accidents took place and [42] [43] [44]

considering all the above limitations, advantages, limitations and incidents, few findings are listed below.

1. Efficient software programming is critically important to properly articulate decision making capabilities in automated vehicles to avoid unusual disasters

2. From several incidents that took place in the recent years, it is essential to have human intervention rather than fully computer driven to take over in emergencies and avoid potentially dangerous situations

A question arises "is autonomous / automated vehicular technology and connected vehicles are distinct technologies? "autonomous vehicles are "The vehicles without communication to other vehicles [45] where as "connected vehicles is a combination of human driven and computer driven. They allow the vehicles to connect and communicate with each other, the building block of Internet of vehicle [46] . Figure 2 shows the building blocks of IoV for intelligent transportation system (ITS). one example of vehicle functionality include in connected cars is GPS that guides the routes to the drivers. In comparison to autonomous vehicles, functional devices will supply information to the drivers to help them to make safer decisions. connected vehicles are also beneficial to transportation agencies by providing information about road conditions to better plan and deploy efficient resources [47]. Some of the reasons for which automotive industry has extended research initiatives to the evolution of intelligent transportation system are Safety of Road transportation system, traffic congestion and wireless connectivity between vehicles. Figure 2 shows Building blocks of Internet of Vehicle.

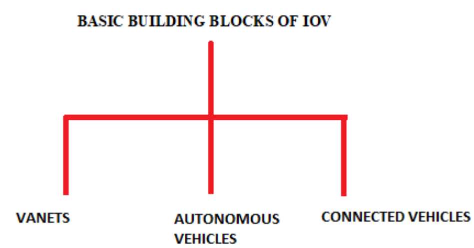

Figure 2 Building blocks of Autonomous Vehicles

One area of IoT that is emerging rapidly in recent years is automobile industry. The new era of IoT is Internet of Vehicles (IoV). It is estimated that by 2035, 80 percent of the road disasters can be avoided [48]. Internet of vehicles is the integration of vehicles to IoT. IoV is regarded as application of IoT in ITS (Intelligent Transportation System). As defined in [49], IoV is a distributed system integrated with three networks inter-vehicle, intra vehicle and vehicle mobile internet. This section gives an overview of evolution of internet of vehicles (IoV) from the early stages of conventional transportation. The overview also describes the pitfalls of the existing technology which has forced to develop the concept of intelligent transportation system (ITS). In VANETS, Each vehicle is treated as a mobile node / wireless router. Each vehicle is connected to other vehicle and forms a network in a certain range [50]. Some of the limitations of VANETS are small mobile networks and mobility constraints [50] , it does not support for various characteristics of urban cities, cannot handle global information in terms of processing capacity. One of the Ideal goals of IoV is to achieve efficient transportation by providing co-ordination, computations among multiple users, multiple vehicles, and multiple things for which it is composed of. secondly, the need of open and integrated network systems for which VANETS, vehicle telematics and connected vehicles have evolved in to one what is called as Internet of vehicles (IoV). Two of the major features of IoV is vehicle networking and vehicle intelligence. VANETS are a sub network of IoV. In comparison to

VANETS, another vehicular technology called as connected vehicles are playing a major role in the field of intelligent transportation system (ITS). connected vehicles are regarded as wireless enabled vehicles as mentioned in [51] . connected vehicles are interacted with sensors called as vehicle to sensor (V2S), vehicle to vehicle (V2V), vehicle to roadside (V2I), vehicle to internet (V2I) as shown in figure 2. The objective of connected vehicles is to make aware of traffic environments to people for safe journey and to reduce overall traffic congestions and road disasters. connected vehicles are considered as the building blocks of internet of vehicles enabling the future intelligent transportation system (ITS) [52]. internet of vehicles (IOV), a new vehicular technology envisioned at betterment of future transportation system (ITS). It is integrated with features of data gathering, data exchange, data computing and processing.

Figure 3. Connected Vehicles [53]

3. Interoperability

Internet of vehicles, a platform where vehicles communicate with each other from the status obtained about the road conditions and vehicles supplied from myriad of sensors. information exchange is one of the critical issue when dealing with systems of different characteristics which could impact even system performance since the devices are heterogeneous and generates huge amount of data. when the devices are manufactured by different companies, it becomes essential to provide coherent services to users. In order for IoV to be widely adaptable and to make it reliable, issues and challenges should be addressed which in other case could even impact the overall performance. As in [54] , some of the issues and challenges highlighted are standardization, reliability, security, mobility and big data. Lack of standardizations could even make the vehicular communication difficult since information exchange plays a vital role in vehicle to vehicle (V2V) communications. secondly, real world data received from sensors should be accurate to avoid terrible incidents to take place. interoperability could arise when manufacturers develop their systems on different platforms, different terminologies and at different times with disparate data sources which results in lack of standardization. Several solutions to interoperability problems are addressed in literature. however, over a certain period of time, the level of success achieved was not enough to mitigate the interoperability problems because of the dynamic nature of data and the way the manufacturers represent data.

Interoperability is of three types:

1. Syntactic Interoperability
2. Semantic Interoperability
3. Cross – Domain Interoperability

Syntactic Interoperability: When two devices are capable of communicating with each other. Data formats and communication protocols are specified
XML, SQL standards are the examples of syntactic interoperability
Semantic Interoperability: When two devices are capable of interpreting the data received from each other with High accuracy and in a meaningful manner. Figure 3 below shows Interoperability in various domains in the context of smart cities.

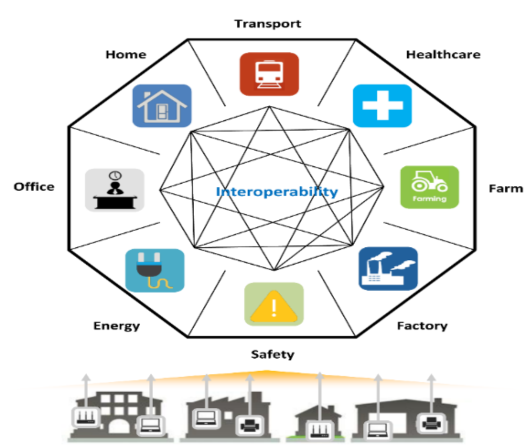

Figure 4. Interoperability in all Domains [55]

Cross-Domain Interoperability: When systems of different domains interact in information exchange to fulfill their goals. one of the major research challenges in IOT domain is "How do we Integrate physical devices effectively "? inspite of several middle ware solutions and protocols, seamless integration of physical devices still persists. Another research challenge is "how do we collect and manage the data in mobile and dynamic environments?" like in connected vehicles which is a kind of real time reactive application where the devices needs to take real time decisions. Interoperability can be between same product from different vendors and past and future revisions of the same component. Due to lack of standardization, many middle ware solutions were suggested [56] to achieve interoperability as shown in Table 7 below. Middle ware is an intermediate layer between application and IoT devices to deal with interoperability problems where it can provide services to heterogeneous objects. As shown in Table 7, there are several middle ware software's available to deal with heterogeneous objects and provide interoperability among them. Examples of middle ware are shown in Table 7. However, each middleware has a different programming and architectures due to which it cannot advocate and facilitate in connecting IOT devices. All the middle ware solutions discussed in Table 7 are developed from the perspective of specific applications. One way to achieve semantic interoperability is "common information exchange reference model" [57]. The interoperability is composed of two major processes. One is data format which means what kind of data type is chosen to exchange the information and second is data interpretation. incorrect interpretation of data could lead to ambiguous results. another approach mentioned in [58] is "Plug n interoperate" which is interoperability specifications (IS) independent.

TABLE 7 Middle Ware solutions for Interoperability [56] [59]

Middle Ware	Interoperation
HYDRA	✓
GSN	✓
PARAIMPU	✓
GOOGLEFIT	✓
UBI SOAP	✓
UBI ROAD	✓
CALVIN	✓
NODE RED	✓
PTOLEMYS SWARM LET	✓
SOCRADES	✓
SIRENA	✓
WHEREX	✓

INTEROPERABILITY LAYERS

Interoperability issue is not new but with increasing number of vendors and platforms, it has become a conflict of interest. Hence, it is very essential in IoT domain to get insights of interoperability and to peel away layers of it called as "Interoperability layered approach" to analyze IoT problems.

TABLE 8 Interoperability Layered Approach [60] [61]

Device Layer	This layer is responsible for accommodating and integrating physical devices
Networking Layer	Wireless technologies will play a vital role in this layer. It supports mobility and routing
Middle Ware Layer	This layer is responsible for service discovery endpoints management
Application Service	This is the layer that provides API to user interface
Data and Semantics Layer	It includes data and analytics understanding

4. Motivating Scenario

Internet of Things applications are generally categorized in to two types [59]. One is data collection and analysis in ambient environments such as in medical and agricultural domains. The second application is real time reactive applications such as automobile applications where there is a need to monitor and sense real time data to effectively make accurate decisions. In this section, we try to expose the need of interoperability in a highly dynamic and mobile environments such as connected vehicles where each vehicle is moving at a different speeds, the importance of situational awareness and decision making capabilities in worse scenarios. Some of the sensors that are deployed in vehicles to monitor surrounding environments are object sensors and pose sensors. sensors embedded in vehicles are manufactured by different companies with different data formats [62]. These sensors generates multimodal data that supports different data formats, hence there is a need of proper interpretation of data when it is exchanged between two vehicles. Due to the lack of standardization, there is a need to implement a platform specific systems. Due to the decentralized structure of vehicle to vehicle, it is very crucial to organize a collaboration between vehicles. Also, the information exchange is localized. Whenever two vehicles comes in radio communication range, they connect automatically forming an adhoc network. Let's consider a vehicle to vehicle communication (V2V) scenario, assuming neighboring vehicles and Road side stations. Some of the general data shared between the vehicles is about speed, direction and position of the vehicle. In an environment like IoV where vehicles are moving with varying speeds and exchanges information, several aspects needs to be considered such as delay, accurate measurements, and quick decisions, failure in doing so could lead to disasters. Let's say vehicle 'A' wants to turn right and sends the message to vehicle 'B' in which case the latter vehicle must reduce the speed [63] as shown in figure 5. Now, for both vehicles speed is an important factor. This could arise several concerns. “What is the data format used by vehicle ‘A’ to communicate the message with vehicle ‘B’?” “How much is the execution time required at the intermediate layer so as to process the data, interpret the data in the format described by vehicle ‘B’ to make decisions and to prevent accidents at the intersection areas”. In the literature several middle ware solutions have been developed in IoT domain. Since there is no universally agreed standards, these middle ware solutions have implemented on specific platforms leaving behind the problem of interoperability unsolved.

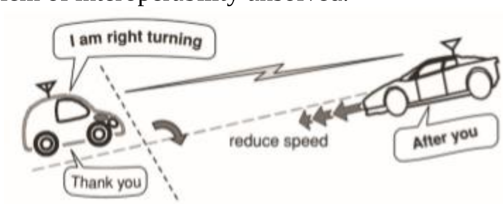

Figure 5 V2V Example [63]

As per SAFESPOT PROJECT, some of the identified situations that could lead to possible road accidents is shown below in Figure 6

Rear End	Head On	Side Swipe, Same Direction	Sideswipe,Opposite Direction
Overtaking	Right turn, Rear End	Right turn , on coming	Left turn , on coming
Left Turn , Rear End	Left Turn, Opposing Thru	Right Angle	Right Turn , Side Swipe
Through with Right	Left Turn , Side Swipe	Through with Left	Left and Right Turn , Side Swipe
Single Vehicle With Parked Car	Single Vehicle With Other Than Parked Car	Vehicle With Pedestrian	Vehicle with bi cycle
Bicycle with pedestrian	Other		

Figure 6 Situations that could lead to Road Accidents (SAFESPOT PROJECT)

Comparative study of interoperability approaches and findings:

TABLE 9 Comparative study of interoperability issues

PAPER	INTEROPERABILITY
[64]	In this paper, non-ionizing radiation data is remotely measured, stored and processed. interoperability issue is discussed but does not provide any solution
[65]	The research paper is mainly focused on proposing solution to interoperability in smart homes because of heterogeneity of devices. Web services has been proposed as solution to solve interoperability in Home environmnets. SOAP technology is used to solve interoperability issue.
[66]	Several issues and challenges were discussed. Middle ware solutions were suggested for IoT interoperability
[67]	Middle ware approach is used to solve the issue of interoperability in home environments
[68]	Several issues and challenges were discussed. Middle ware solutions were suggested for IoT interoperability
[69]	Interoperability issue is discussed for military applications
[70]	Interoperability is implemented considering specific platform. A middle ware platform called multiroom bridge adapter is discussed in this paper
[71]	Several issues and challenges were discussed. Middle ware solutions were suggested for IoT interoperability
[72]	Interoperability is implemented for a specific platform considering virtual overlay network
[73]	middle ware solution is discussed for a specific platform
[74]	A system architecture is discussed for FIESTA-IoT platform developed test beds for the researchers to deal with interoperability issues
Proposed paper	In the proposed paper, existing middle ware solutions were discussed. The significance of interoperability and its implications were discussed in IoV domain specific to V2V technology.

CONCLUSION

In this paper, we have analyzed the current solutions for interoperability and explored most of it. To enable interoperability effectively, many reasearchers are striving to achieve aforementioned challenges. Several middle ware solution were developed confined to specific platform as discussed in III. Furthermore, the significance of interoperability in IoV is discussed considering motivating scenario. A comparative study is done mainly focusing on interoperability issues and approaches suggested by authors to achieve it. However existing middle ware solutions for interoperability does not provide a unique solution for all platforms but implemented on a specific platforms. Due to lack of standardization which implies a broad area of research still persists and needs extensions for the implementation. IoT interoperability is a challenge that is addressed widely. Relying on middle ware and common interface exchange model approaches may result in scalability and performance issues. The work presented in this research proposal elaborates interoperability requirement in connected vehicles. In providing interoperability among connected vehicles, data representation must be independent regardless of operating platform. For effective interoperation of connected vehicles, latency is significant and crucial for real time application. The latency has considerable impact towards performance of proposed protocol (standardized protocol) in managing connected vehicles. The achievement of IOT interoperability could make the effective and efficient communication possible between the devices.

REFERENCES

[1] E. Brown, ""Who Needs the Internet of Things?"," 13 September 2016. [Online]. Available: https://www.linux.com/news/who-needs-internet-things. [Accessed 22 August 2018].

[2] E. Brown, " "21 Open Source Projects for IoT"," 20 September 2016. [Online]. Available: https://www.linux.com/NEWS/21-OPEN-SOURCE-PROJECTS-IOT. [Accessed 22 august 2018].

[3] " "Internet of Things Global Standards Initiative"," 26 june 2015. [Online]. Available: https://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx. [Accessed 22 August 2018].

[4] D. Hendricks, " "The Trouble with the Internet of Things"," 10 August 2015. [Online]. Available: https://data.london.gov.uk/blog/the-trouble-with-the-internet-of-things/. [Accessed 22 August 2018].

[5] D. Evans, "The Internet of Things How the Next Evolution of the Internet Is Changing Everything," CISCO white paper, 2011.

[6] A. Nordrum, "IEEE Spectrum," 18 August 2016. [Online]. Available: https://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated. [Accessed 22 August 2018].

[7] "A walk through Internet of Things (IoT) Technology Roadmap.," IOT Makers, 2017.

[8] s. kashyap, "10 Real World Applications of Internet of Things (IoT) – Explained in Videos," 26 august 2016. [Online]. Available: https://www.analyticsvidhya.com/blog/2016/08/10-youtube-videos-explaining-the-real-world-applications-of-internet-of-things-iot/. [Accessed 22 September 2018].

[9] P. Sethi and S. R.Sarangi, "Internet of things:Architecture,Protocols and Applications," *Journal of Electrical and Computer Engineering,* vol. 2017, p. 25, 2017.

[10] O.-Y.-Z.-H. I.Mashal, "Choices for Interaction with things on Internet and Underlying issues," *AdHoc Networks,* vol. 28, pp. 68-90, 2015.

[11] O. a. M.Masud, "Towards internet of Things:Survey and Future Vision," *International Journal of Computer Networks* , vol. 5, no. 1, pp. 1-17, 2013.

[12] T.-J.-Y.-Y. M.Wu, "Research on the architecture of Internet of things," in *in proceedings of the 3rd international conference on advanced computer theory and engineering(ICACTE'10),* China, 2010.

[13] S. S. R.Khan, "Future Internet:the internet of things architecture,possible applications and key challenges," in *,"in proceedings of the 10th International conference on frontiers of Information technology(FIT'12),* 2012.

[14] H. Ning and Z. Wang, "Future Internet of Things Architecture: Like Mankind Neural System or Social Organization Framework?," in *IEEE Communications Letters* , 2011.

[15] C. M.Weyrich, "Reference Architectures for the internet of things," *IEEE Software,* vol. 33, no. 1, pp. 112-116, 2016.

[16] R. J.Gubbi, "Internet of things(IOT): a vision ,architectural elements , and future directions," *Future Generation Computer Systems,* vol. 29, no. 7, pp. 1645-1660, 2013.

[17] R. F.Bonomi, "Fog computing:a platform for internet of things and analytics," *Bigdata and Internet of things:A Road Map for Smart Environments,* pp. 169-186, 2014.

[18] F. Bonomi, R. Milito, J. Zhu and S. Addepalli, "Fog computing and its role in the internet of things," *Proceedings of the first edition of the MCC workshop on Mobile cloud computing,* pp. 13-16, 2012.

[19] I. Stojmenovic and S. Wen, "The Fog computing paradigm: Scenarios and security issues," in *2014 Federated Conference on Computer Science and Information Systems*, Warsaw, Poland, 2014.

[20] M. Aazam, P. P. Hung and E.-N. Huh, "Smart gateway based communication for cloud of things," in *2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, Singapore, 2014.

[21] A. F. S. L. N. S. P.D.Binotto, "A Cloud-based Architecture for the Internet of Things targeting Industrial Devices Remote Monitoring and Control," *Elseveir,* vol. 49, no. 30, pp. 108-113, 2016.

[22] " "'Phantom Auto' will tour city"," The Milwaukee Sentinel, 1926.

[23] P. J. Antsaklis, K. M. Passino and S. Wang, " "An Introduction to Autonomous Control Systems"," *IEEE Control Systems,* vol. 11, no. 4, pp. 5-13, 1991.

[24] B. insider.com, "Autonomous cars could save the US Dollars1.3 trillion dollars a year," INFOGRAPHIC, 2014.

[25] J. Miller, "Self driving car technologys benefits," The energy collective.com, 19 August 2014.

[26] R. Whitwam, "How googles self driving cars detect and avoid obstacles," Extreme Tech, 2014.

[27] M. Ramsey, "Self driving cars could cut down on Accidnets," *The Wall Street Journal,* 2015.

[28] L. Gomes, ""Hidden Obstacles for Google's Self-Driving Cars"," MIT Technology Review, 2014.

[29] N. Zhou, " "Volvo admits its self-driving cars are confused by kangaroos"," The Guardian. , 2017.

[30] E. Badger, ""5 confounding questions that hold the key to the future of driverless cars"," Wonk Blog. The Washington Post, 2015.

[31] ""Hackers find ways to hijack car computers and take control"," 2013.

[32] P. E. Ross, " "A Cloud-Connected Car Is a Hackable Car, Worries Microsoft"," *IEEE Spectrum,* 11 April 2014.

[33] R. Moore-Colyer, ""Driverless cars face cyber security, skills and safety challenges"," 24 April 2015. [Online]. Available: www.v3.co.uk.. [Accessed 27 August 2018].

[34] B. Denaro, "Civil Maps – Automated Vehicle: Myth vs. Reality," ITS International, 2016.

[35] D. Light, " A Scenario" The End of Auto Insurance," Celent, 2012.

[36] C. Mui, " "Will The Google Car Force A Choice Between Lives And Jobs?"," Forbes, 2013.

[37] ""Mass unemployment fears over Google artificial intelligence plans"," London, 2013.

[38] S. Gibbs, ""Self-driving bus involved in crash less than two hours after Las Vegas launch"," The Guardian, 2017.

[39] G. Bensinger and T. Higgins, ""Video Shows Moments Before Uber Robot Car Rammed Into Pedestrian"," Wall Street Journal, 2018.

[40] A. Lubben, ""Self-driving Uber killed a pedestrian as human safety driver watched"," 2018.

[41] ""For the first time, Google's self-driving car takes some blame for a crash"," Washington post, 2016.

[42] J. Horwitz and H. Timmons, ""There are some scary similarities between Tesla's deadly crashes linked to Autopilot"," Quartz, 2018.

[43] ""There are some scary similarities between Tesla's deadly crashes linked to Autopilot"," China State Media, 2016.

[44] R. Felton, " "Two Years On, A Father Is Still Fighting Tesla Over Autopilot And His Son's Fatal Crash"," Jalopnik, 2018.

[45] M. Parent, "Automated Vehicles: Autonomous or Connected?," in *2013 IEEE 14th International Conference on Mobile Data Management*, Milan, Italy, 2013.

[46] N. L. C. Z. S. W.Mark, "Connected Vehicles:Solutions and Challenges," *IEEE Internet of Things Journal,* vol. 1, no. 4, pp. 289-299, 2014.

[47] S. Murtha, "Autonomous vs connected vehicles – what's the difference?," SNC LAVALIN, 2 October 2015. [Online]. Available: https://www.atkinsglobal.com/en-gb/angles/all-angles/autonomous-vs-connected-vehicles-whats-the-difference. [Accessed 27 August 2018].

[48] IEEE, "From IoT to IoV: The Internet of Vehicles," *IEEE Transmitter,* 25 may 2018.

[49] "White Paper of Internet of Vehicles (IoV)," APEC, China, 2014.

[50] W. S. L. J. L. Z. S. Q. YANG Fangchun, "An Overview of Internet of Vehicles," *VEHICULAR NETWORKING,* 2014.

[51] N. Lu, N. Cheng, N. Zhang, X. Shen and J. W. Mark, "Connected Vehicles: Solutions and Challenges," *IEEE Internet of things journal,* vol. 1, no. 4, 2014.

[52] N.Liu, "Internet of vehicles:Your next connection," *Huawei Win Win,* vol. 11, pp. 23-28, 2011.

[53] J. M. GITLIN, "WHY DIDN'T I THINK OF THAT? — Qualcomm covers all the bases with a cellular "vehicle-to-everything" chipset," 9 1 2017. [Online]. Available: https://arstechnica.com/cars/2017/09/qualcomm-covers-all-the-bases-with-a-cellular-vehicle-to-everything-chipset/. [Accessed 8 25 2018].

[54] M. T. a. S. M. M. Matthew N. O. Sadiku, "Internet of Vehicles: An Introduction," *International Journals of Advanced Research in Computer Science and Software Engineering* , vol. 8, no. 1, p. 13, 2018.

[55] J. K. a. J. Y. Minwoo Ryu, "Integrated Semantics Service Platform for the Internet of Things: A Case Study of a Smart Office," *Sensors* , vol. 15, no. 1, pp. 2137-2160, 2015.

[56] C. f. i. w. t. o. i. a. u. issues, "Ibrahim Mashal;Osama Al Saryrah;Tein-Yaw Chung;Cheng-Zen Yang;Wen-Hsing Kuo;Dharma P.Agarwal," *Elseveir,* vol. 28, pp. 68-90, 2014.

[57] C. Ivanov, "The Way to Exchange: What Is the Common Information Model? [Guest Editorial]," *IEEE Power and Energy Magazine,* vol. 14, no. 1, pp. 22-28, 2016.

[58] P. Maló, M. Mateus, B. Almeida and T. Teixeira, "Measuring Data Transfer in Heterogeneous IoT Environments," in *2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing,* Portugal, 2013.

[59] M. G. V. M. S. N. a. Q. Z. S. Anne H. Ngu, "IoT Middleware: A Survey on Issues and Enabling Technologies," *IEEE Internet of things Journal,* vol. 4, no. 1, p. 20, 2017.

[60] J. Pearlman and P. S. J. W. G. A. O. p. R. S. d. campbell, Report of the Research Coordination Network RCN:OceanObsNetwork Facilitating Open Exchange of Data and Information edited by Pearlman, Jay, Williams III, Albert and Simpson, Pauline, OCEAN RCN , 2013.

[61] G. Audin, "Peeling Away the Layers of IoT Interoperability:Internet of Things interoperability is more than a network connection.," no jitter, 2017.

[62] J. h. c. B. a. r. P. F. D. c. Soumya Kanti Datta, "Vehicles as connected ResouRces:Opportunities and Challenges for the Future," *ieee vehicular technology magazine* , p. 10, 21 April 2017.

[63] S. K. a. S. T. N. Hashimoto, " “A cooperative assistance system between vehicles for elderly drivers,”," *IATSS Research,* vol. 33, no. 1, pp. 35-41, 2009.

[64] F. Vega, J. Pantoja, S. Morales, O. Urbano, A. Arevalo, E. Muskus and C. Pedraza, "An IoT-based open platform for monitoring non-ionizing radiation levels in Colombia," in *2016 IEEE Colombian Conference on Communications and Computing (COLCOM)*, Cartagena, Colombia, 2016.

[65] T. Perumal, A. R. Ramli, C. Y. Leong, S. Mansor and K. Samsudin, " Interoperability Among Heterogeneous Systems in Smart Home Environment," in *2008 IEEE International Conference on Signal Image Technology and Internet Based Systems*, Bali,Indonesia, 2008.

[66] I.-Y.-Z.-H. P.Agrawalc, "Choices for interaction with things on Internet and underlying issues.," *ELSEVIER,* vol. 28, pp. 68-90, 2015.

[67] C.-E. Lee and K.-D. Moon, "Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware.," in *IEEE,* Las Vegas, NV, USA, 2005.

[68] P. S. a. S. R. Sarangi, "Internet of Things: Architectures, Protocols, and Applications," in *Journal of Electrical and Computer Engineering*, Delhi, 2017.

[69] W. E. Hoekstra, " "'System Concepts for Integrated Air Defense of Multinational Mobile crisis reaction forces"," in *"'System Concepts for Integrated Air Defense of Multinational"*, Valencia, Spain, 2000.

[70] M.-J. Lee, H.-M. Jeong, J.-Y. Oh and S.-J. Kang, "Multimedia room bridge adapter for seamless interoperability between heterogeneous home network devices," in *IEEE,* Las Vegas, NV, USA, 2006.

[71] E. Patti and A. Acquaviva, "IoT platform for Smart Cities: Requirements and implementation case studies," in *2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)*, Bologna,Italy, 2016.

[72] H. Park, J.-H. Park and N. Kim, "A framework for Interoperability of Heterogeneous devices in Ubiquitous Home.," in *2010 Second International Conference on Advances in Future Internet*, Venice , Italy, 2010.

[73] R. K. Lomotey, J. Pry, S. Sriramoju, E. Kaku and R. Deters, "Middleware Framework for IoT Services Integration.," in *2017 IEEE International Conference on AI & Mobile Services (AIMS)*, Honolulu, HI, USA, 2017.

[74] F. Carrez, T. Elsaleh, D. Gómez, L. Sánchez, J. Lanza and P. Grace, "A Reference Architecture for federating IoT infrastructures supporting semantic interoperability," in *2017 European Conference on Networks and Communications (EuCNC)*, Oulu, Finland, 2017.

[75] E. I. FRAMEWORK, "European Interoperability Framework," [Online]. Available: http://ec.europa.eu/idabc/servlets/Docd552.pdf?id=19529. [Accessed 5 9 2018].

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