environments. It can operate as a rescue operation in earthquake-stricken areas or deep-sea and space exploration. An alternative advantage of self-reconfiguration is self-repair by changing broken modules. Thus, the system is not down waiting to be repaired where human intervention latency could prove to be disastrous. An example would be in a nuclear plant where task-orientation is extremely important. Table 4 is derived from table 1 where all task-oriented participatory sensing systems are analyzed.

Table 4: Task-Oriented Participatory Sensing Systems

Cite	Description	Contributions	Strengths	Limitations
Dong, Z., *et al* (2014)	REPC: Reliable and Efficient Participatory Computing for Mobile Devices	Effective randomized task assignment framework. Minimize the number of tasks to be executed by individual devices	Achieved reliable participatory computing with very low system overhead in various system settings.	No real-time decision from the task manager. The system does not address the short life span of data collection in participatory sensing systems.
Moraes, A.L.D. *et al* (2014)	A Meta-Model for Crowdsourcing Platforms in Data Collection and Participatory Sensing	Provides a multi-model to fit generic solutions	Data collected and participatory sensing help to better understand Environmental issues	The trustworthiness of data cannot be identified.
Mrazovic, P. and Matskin, M., (2015)	MobiCS: Mobile Platform for Combining Crowdsourcing and Participatory Sensing	Proposed an architecture that takes different nodes of mobile sensing to treat carriers as intelligent problem solvers	Trustworthiness and quality control were implemented	Task allocation was not a complete success due to the accuracy problem
Cheny, J. and Zhao, D (2016)	A Quality-Aware Attribute-based Filtering Scheme for Participatory Sensing	Data quality has been ensured to encourage more participant to contribute to the sensing framework	The server will assess participant whose data satisfies the quality policy by ensuring confidentiality and accuracy	Accuracy has been preserved by data latency has not been addressed
Zhang, B. *et al* (2016)	Robots-Aided Participatory Crowdsourcing with Limited Task Budget	The system caters data to be processed by the robots-aided system	The system provides additional services to existing Participatory sensing framework	The system does not cater for reliability and trustworthiness of data
Jadoo, S. and Nagowah, L (2017)	A Hybrid Approach to Cater for Identity and Location Challenges in Crowdsourcing Applications	Privacy of users has been applied using encryption and encoding	Hashing technique has been used to protect against Data privacy	The system proposed does not cater for different levels of attacks
Krishna, M.B (2018)	Group-based Incentive and Penalizing Schemes for Proactive Participatory Data Sensing in IoT Networks	The proposed system defines incentive and penalizing factors	Data accuracy, reliability, and consistency has been implemented in the framework.	The system has a limited amount of user involved

5. General Results

In this section, the 24 mobile participatory sensing systems are evaluated against the five criteria which are accuracy, reliability, real-time, trustworthiness, and scalability.

5.1. Accuracy

In a participatory sensing application, providing a service will largely depend on how accurate the data has been captured. Accuracy is a requirement that is desired before any processing to provide adequate services in a participatory application. Over the years, many researchers [1, 12] have largely contributed to the participatory sensing systems. At the end of this section is an analysis of the impact of "accuracy" in those systems. Accuracy can be defined as the acceptable level of measurement with an accepted standard.

5.2. Real-time Latency

A machine cannot act on something, such as providing a service instantaneously, and the amount of waiting time between an input and its output is called latency. In a participatory system, to preserve delay between input and output such that it is non-existent, the latency must be low, that is the system must react in real-time. Consistent latency is the most desirable requirement in a system. The amount of data being collected or pushed from participants, and the constantly changing environment data should be relatively low.

5.3. Reliability

In a participatory system, when data is sent for processing, it is important to check if the captured data is still relevant. For example, if a participant has captured data and is disconnected from the network, it is important to check the reliability of the data. When the user will connect to communicate the data to the server, the relapsing of the data has changed. As such reliability can be defined as the ratio of data being collected that produces correct output to the total number of participants in a participatory sensing system.

5.4. Trustworthiness

It will check whether a malicious person will send irrelevant data to the server. Often while capturing data, several types of noise adversely affect the collected data and when this data is sent to the server to map an environmental change, the system reports inaccurate data to the users. Thus, the application server must have the necessary mechanisms to assess the trustworthiness of the collected data so that malicious contributions, corrupted, and incomplete data can be detected.

5.5 Scalability

It is described as the capability of a process, network, software, or association to develop and manage increased demand. A system or software that is labeled as accessible has a benefit because it is more flexible to the varying needs or demands of its users. Scalability is the property of systems to deal with a developing measure of work by adding assets to the systems. In a participatory system, the number of participants is not fixed, instead, it varies, and to handle the constant change of participants, the system must be scalable.

Table 5 presents the evaluation of the 24 mobile participatory sensing systems against the five criteria. Three benchmarks are used as the level of acceptance which is: low, average, and critical. A rating analysis is performed based on the following details:

- Low → 0 or 1
- Average → 2 or 3
- Critical → 4 or 5

Table 5: Evaluating the Participatory Sensing Systems

Cite	Accuracy	Real-time latency	Reliability	Trustworthiness	Scalability	RATING
Environmental Participatory Sensing Systems						
Chen, H *et al*. (2014)	Average: 3	Critical: 4	Critical: 4	Critical: 4	Low: 0	15
Szabó, r., *et al* (2014)	Average: 3	Critical: 5	Critical: 4	Critical: 4	Low: 0	16
Zaman, J. *et al* (2015)	Low: 1	Low: 1	Critical: 4	Critical: 4	Low: 0	10
Gupte, S *et al* (2015)	Critical: 4	Critical: 4	Critical: 4	Critical: 4	Average: 3	19
Alswailim, M.A., *et al* (2016)	Critical: 4	Average: 3	Critical: 4	Critical: 4	Low: 0	15
Zhang, B. *et al* (2016)	Critical: 4	Average: 3	Critical: 4	Critical: 4	Critical: 4	19
Chifor, B.C. (2016)	Critical: 5	Average: 3	Low: 1	Critical: 4	Low: 0	13
Sei, Y. and Ohsuga, A (2016)	Average: 3	Average: 3	Low: 1	Low: 1	Low: 0	8
Saremi, F. and Abdelzaher, T. (2016)	Low: 1	Low: 1	Critical: 4	Critical: 4	Low: 0	10
Tefera, M.K. and Xiaolong, Y. (2017)	Average: 3	Average: 3	Critical: 4	Critical: 4	Low: 0	14
Melo, G *et al* (2017)	Average: 3	Critical: 4	Critical: 4	Critical: 4	Average: 3	18
Total per Column	**34**	**34**	**38**	**41**	**10**	**157**
People-Oriented Participatory Sensing Systems						
Restuccia, f. *et al.* (2014)	Low:1	Low: 1	Critical: 4	Critical: 4	Critical: 4	14
Wu, F.J. *et al* (2014)	Critical: 4	Average: 3:	Critical: 4	Critical: 4	Average: 3	18
Wu, F.J. *et al* (2015)	Average: 3	Average: 3	Critical: 4	Critical: 4	Average: 3	17
Mousa, H *et al* (2017)	Critical: 4	Average: 3	Critical: 4	Critical: 4	Average: 3	18
Ji, X *et al* (2017)	Low: 1	Low: 1	Critical: 4	Critical: 4	Low: 0	10
Khoi, N.M (2017)	Critical: 4	Critical: 4	Critical: 4	Critical: 4	Low: 0	16
Total per Column	**17**	**15**	**24**	**24**	**13**	**93**
Task-Oriented Participatory Sensing Systems						
Dong, Z., *et al* (2014)	Critical: 4	Critical: 4	Critical: 4	Critical: 4	Low: 0	16
Moraes, A.L.D. *et al* (2014)	Average: 3	Average: 3	Critical: 4	Critical: 4	Average: 3	17
Mrazovic, P. and Matskin, M., (2015)	Average: 3	Critical: 4	Critical: 4	Critical: 4	Low: 0	15
Cheny, J. and Zhao, D (2016)	Average: 3	Critical: 4	Critical: 4	Critical: 4	Average: 3	18
Zhang, B. *et al* (2016)	Low: 1	Low: 1	Critical: 4	Critical: 4	Low: 0	10
Jadoo, S. and Nagowah, L (2017)	Average: 3	Critical: 4	Critical: 4	Critical: 4	Low: 1	16
Krishna, M.B (2018)	Critical: 4	Critical: 4	Critical: 4	Critical: 4	Low: 1	17
Total per Column	**21**	**24**	**28**	**28**	**8**	**109**

6. Discussion

In this section, the 24 mobile participatory sensing systems are discussed as per the categories identified in section 4 and section 5. Potential challenges are identified and discussed.

6.1. Environmental Participatory Sensing System Challenges

The environmental participatory sensing system has a high impact on our daily life. From the 24 systems stated above, 11 systems have been identified as an environmental participatory sensing system and the overall rating is 157. Different systems such as traffic monitoring, air monitoring, water monitoring, or sound monitoring have contributed hugely to this category and there is an increasing demand for such systems. Some researchers [27] have shown how critical such applications are now. It has also been noticed that these systems are limited in terms of users' participation, that is, the rate at which users are entering or leaving the networks. Researchers are investing a lot of effort into how to propose an alternative to issues rather than consolidating existing systems. Below is a representation of the five criteria's assessment within the environmental category:

- Accuracy → 34
- Real-Time → 35
- Reliability → 37
- Trustworthiness → 41
- Scalability → 10

6.2. People-Oriented Participatory Sensing system challenges

The technological recognition of users is important for the positive acceptance of People-Oriented Participatory Sensing systems. For this category, 6 systems have been identified as people-oriented systems with a rating of 93. Yet, it is crucial to explore these systems with diverse groups of participants since each user has an altered kind of contact with the systems. Some researchers [13] have given proof of the importance of such systems, with direct response abilities. Therefore, there is a great necessity to perform research. Most of the services provided are restricted to regions, developed countries, or the performance of devices. No proper research has been conducted to see how these services can integrate existing platforms or to monitor a trial version in developing countries. Below is a representation of the five criteria's assessment:

- Accuracy → 17
- Real-Time → 15
- Reliability → 24
- Trustworthiness → 24
- Scalability → 13

6.3. Task-Oriented Participatory Sensing System Challenges

Nowadays, the adoption and development of Task-Oriented Participatory Sensing systems are becoming fundamental in participatory sensing systems. 7 systems identified in table 4 represent task-oriented systems, with a rating of 109. These structures can function in a multidisciplinary location and be technology autonomous. Some researchers [33] have shown the interoperability and the immense opportunities of such systems. There is an apprehension among employees of being replaced by these systems to cut costs. This is due because researchers are focusing on how technology can increase productivity while decreasing cost and death rather than proposing how humans can interact with these systems to increase efficiency. Below is a representation of the five criteria's assessment:

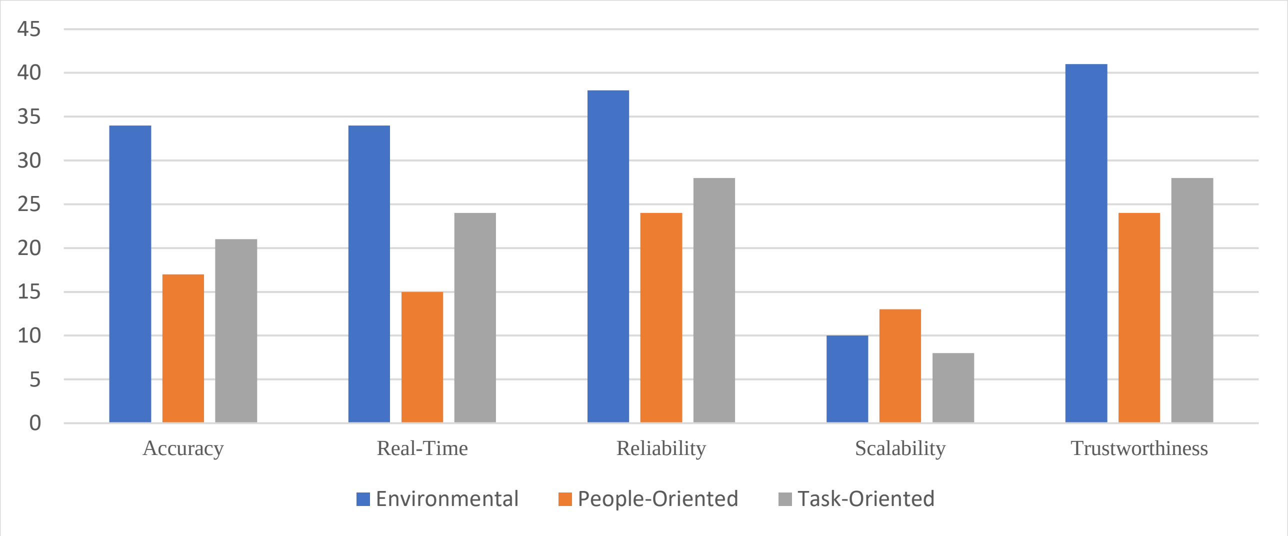
- Accuracy → 21
- Real-Time → 24
- Reliability → 28
- Trustworthiness → 28
- Scalability → 8

From this review, it has been noticed there is an important consideration for environmental systems. The reliability and trustworthiness of data remain critical criteria for the participatory sensing systems. One criterion that demand further attention is scalability. Most of the systems identified have either a limited number of participants during testing or participants are not willing to join and share information over the network. Table 6 shows a classification of the five criteria as per the priority of the systems.

Table 6: General evaluation of Participatory Sensing Systems

Criteria	Environmental	People-Oriented	Task-Oriented
Accuracy	34	17	21
Real-Time	34	15	24
Reliability	38	24	28
Scalability	10	13	8
Trustworthiness	41	24	28
Grand Total	**157**	**93**	**109**

Figure 1: General evaluation of Participatory Sensing Systems



6.4. Open Research Challenges

Mobile participatory sensing systems possess immense opportunities in different spheres of socio-economic activities. There are numerous challenges in these real-time monitoring systems such as data privacy, completeness of data, cost-effectiveness, user trust, incentives to encourage the participation of users, and many more. Since data are collected from numerous users in participatory systems, two important challenges are to ensure the reliability and trustworthiness of the data. Data from participatory systems are sensed, analyzed in real-time and actions are taken accordingly. Therefore, reliability and trustworthiness are of utmost importance. Many research challenges are still open due to these complexities. These are discussed in the following section and are interpreted as scalability, user participation, efficiency/power consumption, and interoperability.

Interpretation of Results

From table 6, a detailed analysis has been performed from the 5 criteria which showed where there is a need for future research and what is the ongoing domain interest. Scalability is a domain where improvement is required due to the increasing number of devices and users. On the other hand, trustworthiness and reliability are the areas where researchers are exploring and contributing heavily.

Scalability

Mobile participatory sensing systems should be able to define the maximum number of users and devices. In an environmental system, the targeted audience should be on a larger scale due to the constant changes of data. Therefore, scalability will focus mainly on the number of users participating in the system as it is difficult to give an exact amount of users in such systems. For a task-oriented system, it must harness a greater set of processors. Therefore, it must scale to a higher amount of processors compatred to the existing multiprocessor systems, such as networks of workstations. Thus, scalability will have a different behavior depending on the category targeted.

User Participation

The number of participants is a critical characteristic to ensure proper service. Users are expecting to have accurate and reliable services from the system, else participants will not be willing to use and participate. Thus, there should be a proper mechanism, architecture, or protocol to increase the participation of users. Some researchers [16] have proposed incentives depending on the user's participation while others have proposed a reputation model [16]. Nevertheless, there is a big challenge to encourage the users to capture, send data, and to use the services.

Efficiency/Power Consumption

Data should be continuously sensed and captured to prove a real-time service. This addresses the limited power resources which mobile devices and sensor nodes possesses. Futher research should be conducted to provide a "dormant-active" state of sensing devices or optimization algorithms [8]. The in depth research could apply to a limited degree to report mobile participatory sensing systems topics such as node localization, optimal deployment, and data aggregation.

Interoperability

A mobile participatory system is highly desirable to interact with different technologies. To guarantee a general data format, interoperability, and conventions can be used. In a mobile participatory sensing architecture, different types of devices and different types of OS are communicating. Diverse protocols and software are also used to address the topic of interoperability. Therefore, the widespread use of mobile can be used to report the characteristic of interoperability in such systems.

7. Conclusion

This paper presented a review in the state-of-art mobile participatory sensing systems and categorized the systems as environmental, people, and task-oriented with a specific focus on topics and experiments related to mobile participatory sensing systems. Nowadays most of the mobile phones are equipped with sensors and various applications are dependent on the data being generated by these sensors. Researchers have started and are exploring this technological solution to enhance the provision in the different categories. In this paper, 24 mobile participatory sensing systems from 2013 to 2018 are evaluated to improve ongoing research/systems and various prominent problems are defined. From the results, it is seen that there is a demand for mobile participatory sensing systems, especially environmental systems. Moreover, people-oriented, and task-oriented participatory sensing systems appear to be gaining in popularity and there are a number of pressing challenges that needs to be overcome. Researchers have shown how critical data reliability and trustworthiness of data is, without neglecting the other criteria identified in this paper. However, as pointed out in this paper, several challenges remain to be addressed to attain an almost flawless mobile participatory sensing systems. In the near future, the evolution of mobile participatory sensing systems can significantly improve the day to day life of people. The main challenges in such systems were outlined, and areas that researchers should investigate futher for motivating users to participate were discussed.

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