A Reference Architecture for Dynamic IoT Environments Using Collaborative Computing Paradigms (CCP-IoT-RA)

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Keywords: IoT Reference Architecture, Collaborative Computing Paradigms, Architecture Models, System Software Architecture, Collaborative Computing, Collaborating Paradigms, Dynamic IoT Environments.

Abstract: Collaborative Computing Paradigms (CCP) has shown the potential to overcome challenges in dynamic IOT environments. CCP's features are interconnection and interplay, dynamic distribution of data processing, fluidity of computing across paradigms, storage and data management across participating paradigms, and scalability and extendability of the systems software architecture. Reference Architecture and Models are known to provide a blueprint, that can be applied across applications domains, and thus can potentially accelerate the development and deployment of systems software. Using the features of CCP, this paper proposes a RA for dynamic IOT environments using the collaborative computing paradigm (CCP-IOT-RA). Proposed CCP-IOT-RA reference architecture has been applied to commercial and telematics applications like building automation and vehicle and driver behaviour, demonstrating it's versatility and effectiveness.

1 INTRODUCTION

The Internet of Things (IOT) is maturing and evolving, with a significant number of solutions already deployed across various application domains. The challenges within dynamic IOT environments persist, driven by the heterogeneity of smart sensors, devices, data and computing. In addressing these challenges, (Joshi and Deshpande., 2024) have introduced a Collaborative Computing Paradigm (CCP), and validated its efficacy using two applications - data center cooling systems and driver and vehicle behaviour in telematics. They have demonstrated that, by interconnecting and orchestrating various paradigms, it is feasible to ensure the continuous functionality of critical use cases at all times. Data storage, choice of computing paradigm, scalability and extendability have been identified as additional characteristics for the CCP.

In the industrial landscape, systems software architectures have been designed and deployed in diverse application domains. With the demand for satisfying more and more use cases and scenarios, the complexity of applications has increased, and various solutions have also been proposed using a number of architectural styles, models, and schemes. While many architectures and architectural styles have been proposed, and deployed for numerous solutions over past decade, there is a lacuna of Reference Architectures for distributed IOT systems (Muccini and Moghaddam, 2018).

As per (Cavalcante et al., 2015) two architectures (a) IOT ARM and (b) WSO2 are discussed, and concludes that they fulfil the requirements of the IOT architecture, there is a need to go step further. A systematic mapping study of architectures, in (Garcés et al., 2021), shows that reference architectures, especially in IOT, need to be developed further. The IEEE has constituted a working group for IEEE 42042 (Standard for Enterprise, Systems and Software — Reference architectures) for reference architectures (RA) which includes RA for IOT. This is clear evidence of the need to have such reference architectures (IEEE, 2024).

This paper proposes a RA, based on the Collaborative Computing Paradigm, and discusses the applicability to dynamic IOT environments. Proposed RA has been applied to two applications in the domain building automation, and vehicle, and driver behaviour.

The paper is organised as follows. Section 2 provides a brief on characteristics of a typical Reference Architecture. Section 3 develops an evaluation criteria for IOT RA. Section 4 describes the state-of-art, and identifies the Challenges and Issues for a RA in the IoT environments, summarising them based on the published research, Section 5 proposes and develops a

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Reference Architecture for using Collaborative Computing Paradigms to overcome the challenges and issues with a focus on dynamic IoT environments. Section 6 describes and discusses how the applications and use-cases can be realised from the CCP-IOT-RA. Section 7 provides a conclusion and Section 8 provides the details of the future work.

In FIGURE 1, a progression of the content and the development of the reference architecture is shown.

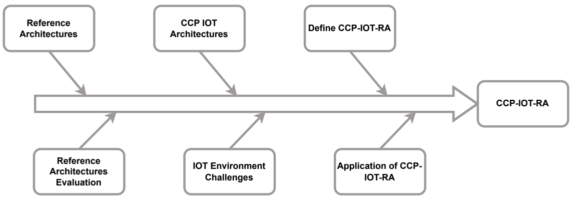

Figure 1: Progression of systems software architecture and IOT architectures to define a CCP-IOT-RA.

2 SYSTEMS SOFTWARE REFERENCE ARCHITECTURE

As systems become increasingly complex, reliant on software, and software intensive; a need for RA arises, which provides a blueprint to design and develop the applications. A RA is known to accelerate the design and development. Additionally, it ensures that the systems developed, and deployed demonstrate shared attributes, and qualities such as security, interoperability, scalability and adaptability.

Developing an architectural design is a non-trivial task, and takes deep knowledge and large experience, both in software and in the target application domain (Palma et al., 2022). Adopting a relevant RA to build an architectural design of software system can accelerate the development process and increase the probability of success of the software intensive systems.

Over past decades, software architectures and systems software architectures, in various forms, directly for applications or as a RA have been proposed, designed, developed and deployed in academia, and industry. A RA for building IOT systems have been discussed in (Kaiser et al., 2023). Generic characteristics, and requirements of RA for IOT have been discussed in (Weyrich and Ebert, 2016).

Systems software requires tailoring, and this is even more prominent when addressing the specific, and unique demands of the IOT systems. Given its dynamic nature, IOT systems necessitates a distinct, and significant emphasis on developing system software architecture and reference architectures.

3 IoT REFERENCE ARCHITECTURE EVALUATION CRITERIA

Dynamic IOT environments are characterised by unique issues, and challenges which have been summarised in (Joshi and Deshpande., 2024). To overcome these, an architecture based on collaborating computing paradigms has been developed, and validated using two applications (a) Data Center Cooling System (b) Vehicle & Driver behaviour.

A set with three dimensions (a) Context (b) Design (c) Goals, as part of the framework for software RA, have been described in (Angelov et al., 2009).

- **Contexts:** IOT systems are complex due to it's multidisciplinary nature. When evaluating the RA, the context is determined by its use by all technical personnel responsible for designing, developing, deploying, and maintaining the system.
- **Designs:** Target design (detailed - High and Low level and formally described) to satisfy the requirements of the system, and systems software.
- **Goals:** While a RA is generic, when adopted to build a system, will have specific goals. Goals may be technical, engineering, performance and business. Scope of the goals, as considered for this evaluation, is limited to the technical, engineering and performance of the systems software. Business goals are specifically not considered.

In this paper these three dimensions are added to the scope, and enhanced for use, in evaluation of the RA for a systems software architecture, and it's application for IOT systems. Thus, a criteria to evaluate the RA is arrived at. It is used for the evaluation of the RA and is summarised in TABLE 1.

Further, this paper proposes a set of quality attributes for the RA. They have been summarised in TABLE 2.

Thus, evaluation proposed and developed in this section is used, in conjunction with the requirements of IOT systems, for designing architectures for specific application and application domains. They are discussed in further sections.

Table 1: Collaborating Computing Paradigm (CCP) Reference Architecture Characteristics.

Characteristics	Description	ID
Interconnection & Interplay	Smart devices, computing paradigms are totally interconnected enabling a complete interplay.	CCP-C1
Dynamic distribution of data processing	Dynamic distribution across computing paradigms, provides increased flexibility and efficient distribution.	CCP-C2
Fluidity of computing across paradigms	Allocation of tasks of computing is dynamic and context driven to ensure outcome.	CCP-C3
Storage and data management across participating paradigms	As per the context the data is processed and stored in a computing paradigm. Ultimately the storage of data (raw and processed) is on the common designated data store.	CCP-C4
Scalability and extendability of the architecture	Integrate new devices, computing paradigms and infrastructure, additional hardware and software components to effectively monitor subsystems, and analyse collected data.	CCP-C5
Context(s)	Specifically from point of view of all the personnel responsible for design, development, deployment and maintenance of the system.	CCP-C6
Goal(s)	Every RA and it's application must satisfy the technical goals set of the system.	CCP-C7
Design(s)	Architectural Design (High Level) and Detailed Design (Low level) to satisfy the requirements of the system.	CCP-C8

Table 2: Reference Architecture Attributes - Proposed.

Attribute	Description	ID
Modularity	Separation of concerns.	CCP-QA1
Variability	Expandable in pre-planned ways.	CCP-QA2
Subsetability	Support production of a subset.	CCP-QA3
Unified	Architectural unification	CCP-QA4
Utility	Useful and function well for people.	CCP-QA5
Robustness	Strong and not be vulnerable for changes.	CCP-QA6
Feasibility	Be practical, implementable and viable.	CCP-QA7
Adaptability	Able to be changed based on requirements, customization and personalization.	CCP-QA8

4 A REF. ARCH. FOR IoT ENVIRONMENTS

4.1 IoT Reference Architecture: State of Art and Requirements

Every IOT system is a highly connected, and a complex system (Weyrich and Ebert, 2016). The authors have compared IOT reference architectures, and have described the requirements for a IOT RA. This paper uses them as requirements criteria to satisfy the necessary, and sufficient condition to be a reference architecture for IOT. The requirements are summarised in the TABLE 3.

4.2 IoT Reference Architectures: Challenges and Issues

IOT environments are unique, and have posed variety of challenges and issues. These challenges and issues are specifically focused on data volume, frequency and processing, data fusion and dynamic computing needs, seamless and multi-interface connectivity, and choice of computing paradigms. The authors (Joshi and Deshpande., 2024), have catalogued the challenges and issues and a summary of the ones relevant to the RA are depicted in TABLE 5

Table 3: IOT Reference Architecture Requirements (Weyrich and Ebert, 2016).

Requirements	Description	ID
Connectivity & Communication	This will involve one-to-one connectivity (unicast), one-to-many (multicast) or data collection, information dissemination to multiple entities. Protocols for exchange of data and information.	CCP-R1
Device Management	Services for managing the device from on-boarding, device configuration, device provisioning and change propagation, Upgrade of devices.	CCP-R2
Data Collection, Analysis and actuation	Ultimately to offer services based on knowledge and information created by computing the data gathered.	CCP-R3
Scalability	Ability to handle the increased number of devices, volume of data for installation of different sizes.	CCP-R4
Security	Trust and privacy across the entire system i.e. all aspects of IOT and all participating entities.	CCP-R5

4.3 IoT Reference Architecture Requirements and Quality Attributes

Any software intensive system, and it's characteristics along with functions require a due consideration of quality attributes. Both are a must to to define a functional system as neither of them stand on their own (Bass et al., 2003). A set of quality attributes have been used to describe the RA.

While the quality attributes have been identified in this paper for the CCP-IOT-RA, they have not been further developed. They have been identified to bring in completeness to the proposed IOT-RA. The set of proposed quality attributes have been identified (Cavalcante et al., 2015) and have been summarised in the TABLE 4.

5 A RA FOR DYNAMIC IoT ENVIRONMENTS (CCP-IoT-RA)

In previous sections, the RA characteristics, and IOT RA requirements, characteristics and attributes have been established. In this section, the RA based on collaborative computing paradigm, for IOT is described.

Criteria for evaluation for satisfying the necessary and sufficient condition for any RA has been based on the RA and IOT RA requirements.

The proposed CCP-IOT-RA must satisfy the following:

- Must have the characteristics of a RA depicted in TABLE 1
- Meet the quality attributes of RA depicted in TABLE 2
- Meet the requirements of IOT Reference Architectures depicted in TABLE 3 and TABLE 4
- Overcome the challenges, and issues for dynamic IOT environments depicted in TABLE 5

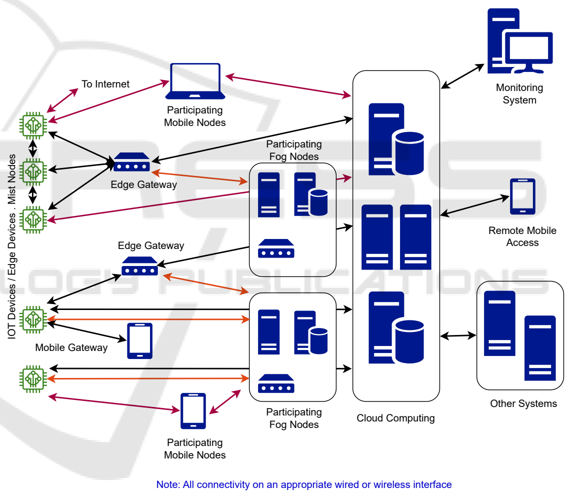

Figure 2: A Reference Architecture for Dynamic IOT Environments CCP-IOT-RA.

CCP-IOT-RA, a RA based on Collaborative Computing Paradigms, for Dynamic IOT Environments is depicted in FIGURE 2. It can be observed, every device and node (fog, mobile, cloud or edge) is interconnected, and a complete interplay is possible. With this, the limitations of the layering do not exit, and communication for data, actuation, data collection and processing can be distributed, by any node, across the computing paradigms.

Devices connect with gateways, fog, and cloud using the wired or wireless interfaces, and choose to communicate (data, upgrade or configuration) based on the context, and the requirement of the applications. Data collected can be transmitted for process-

Table 4: Reference Architecture Requirements and Quality Attributes (Cavalcante et al., 2015).

Characteristics	Description	ID
Interoperability	Among several other devices, services and systems.	CCP-QA1
Device Discovery and Management	Able to discover newer devices and manage them.	CCP-QA2
Context-awareness	Gather information and knowledge of context.	CCP-QA3
Scalability	Manage the increase in devices, data and computing.	CCP-QA4
Management of large volumes of data	Data generated by smart devices.	CCP-QA5
Security, Privacy, and integrity	Related to the data.	CCP-QA1
Dynamic adaptation	High availability and quality of applications execution time.	CCP-QA6

Table 5: Challenges & Issues in IoT Reference Architectures using Computing Paradigms (Joshi and Deshpande., 2024).

Challenge	Description	ID
Data Volume, frequency and Processing	Large volumes of data at high frequencies are collected by large number of devices in the field. Collected data will need to be processed and stored.	CCP-IOT1
Software System Architecture	IOT environments are dynamic and the need is to ensure availability of computing infrastructure and capacity for the data processing task.	CCP-IOT2
Data Fusion and Dynamic Computing	Data fusion needs to build knowledge based on heterogeneous data from variety of sensors.	CCP-IOT3
Seamless and Multi-interface Connectivity	Connectivity with each device and participating node is required for data collection, device upgrades, device management and provisioning.	CCP-IOT4
Fog/Edge Computing and Interplay with Cloud	Computing paradigms are available which can be exploited to build reliable and real-time data processing and actuation.	CCP-IOT5
Choice of Computing Paradigms	Dynamic IOT environments can benefit from the use of most apr computing paradigm in the given context to achieve the goal.	CCP-IOT6
Unified Model and Resource Allocation	With interconnected systems, numerous possibilities, policies and strategies can be employed to ensure efficient utilisation of resources.	CCP-IOT7
Integration and Collaboration	Build synergy among all the participating computing paradigms to ensure scalability.	CCP-IOT8

ing to the nodes (edge, fog, cloud or mobile), and the raw data and processed data can be stored locally on the same node. As part of the storage management, periodically or opportunistically the data, raw and processed, will be transmitted to the Central store.

Diagram shows the following use cases,

- **Use Case 1:** Device has the capability to connect to internet, thus can communicate with the cloud directly, it is also connected to the gateway, and thus has multiple paradigms are available for computing.
- **Use Case 2:** Multiple devices are connected to a gateway, each device is also connected to the Fog Nodes which in-turn can connect to the cloud. Each device also has a direct connectivity to the cloud, thus enabling multiple paradigms to enable applications.
- **Use Case 3:** A device has capability to connect with a mobile node, fog node and also with cloud; which other nodes are interconnected. This ensures that data is collected, and processed on any one of the paradigms.
- **Use Case 4:** A device can be connected to internet, like in use case 3, and will also have access to a gateway node.

Based on the diagram, and functionality description, the criteria for RA is applied, and evaluation results are mentioned. In subsequent sub-sections the RA is developed further.

Classically, the CCP focused on ensuring the connectivity, and data while in the proposed RA, device management, and security have been added as attributes. The way CCP is structured, and design both these additional attributes can be designed using the CCP.

Characteristics of the RA uses the CCP-Systems Software Architecture; thus inherits the characteristics of a CCP and additionally able to satisfy the requirements of an IOT RA stated in Requirements Table 3

Device Management, a function that can be implemented using the CCP-IOT. Security - Trust and privacy become the quality attributes of the CCP-IOT.

5.1 CCP-IoT-RA Requirements

As per the evaluation criteria from previous sections, the CCP-IOT-RA is evaluated for coverage of the requirements of the RA. This is detailed in the TABLE 6. The requirements are mapped to the CCP-IOT-RA characteristics.

5.2 CCP-IoT-RA Characteristics

The CCP-IOT-RA identified characteristics are described and summarised in TABLE 1. The first five characteristics which are from the CCP architecture and the last three are from a functionality perspective that comes in to action for a particular application.

5.3 CCP-IoT-RA Quality Attributes

As part of the evaluation criteria established in previous sections, the CCP-IOT-RA is evaluated against the coverage of the quality attributes of the RA. This is detailed in the TABLE 8. It can be observed that the quality attributes are mapped to the CCP-IOT-RA characteristics.

5.4 Characteristics of CCP-IOT-RA

With the challenges posed by the dynamic IOT environments, the characteristics of the CCP-IOT-RA, the RA, are mapped to the IOT - challenges and issues. The identified challenges and issues become the requirements for the CCP-IOT-RA to fulfil. The mapping along with comments is detailed in TABLE 7.

6 APPLICATIONS OF CCP-IoT-RA

In this section, large systems in commercial and automotive have been discussed. Each system is required to be built using the IOT environments. The CCP-IOT-RA is applied to each of the systems, and sub-systems, and the requirements are mapped to the characteristics of the CCP-IOT-RA. Aim is to ascertain that the CCP-IOT-RA is indeed a RA, which can form a template for all systems, and provide distinct and significant enhancements over classical IOT.

6.1 Building Automation

A typical commercial building, like a commercial complex, with offices and shops, has multiple subsystems, which are deployed to automate the day-to-day operations and upkeep.

Each of the subsystem requirements are listed and discussed briefly, and then mapped to the CCP-IOT-RA. It evident that the CCP-IOT-RA can be used a blueprint to design the entire system to be versatile, and enable the system to work efficiently.

6.1.1 Fire Safety System

Fire Safety equipment is required to be installed, and will need to be monitored, and in particular cases specific actuation is a must.

- **Fire Extinguishers:** Typically weight, and the refill schedule is to be monitored for the fire extinguishers. Based on the CCP-IOT-RA the Use Case 4 may be considered for operations.
- **Fire Sprinklers:** Water pressure is monitored and maintained to a level, such that when the sprinklers are activated water can be pumped for controlling the fire. Sensors are deployed to check water pressure on the lines, and a jockey pump is operated when the pressure drops. Water pressure is monitored continuously and communicated to the nodes for processing. Based on the CCP-IOT-RA the Use Case 2 may be considered for operations.

Salient Features:

- Real-time notifications are a must in case of fire or fault in equipment
- Data collected, raw and processed data, from systems for predictive analytics
- CCP-IOT-RA ensures notifications at all times with interconnection and interplay

The system will notify the designated facility staff for any malfunction in real-time. With CCP system is interconnected - messages and notifications will be sent, using available routes, reliably.

6.1.2 Pubic Toilets Monitoring System

Large buildings have multiple public toilet facilities of various types like family, differently abled, in addition to the standard ones for male/female. Some establishments may have facilities for pets too.

Table 6: CCP-IOT-RA Requirements evaluation.

ID	Requirements	CCP-IOT-RA Mapping	RA Comments
CCP-R1	Connectivity & Communication	CCP-C1	With interconnection and interplay the information dissemination in any modes (unicast or multicast) is enabled; and the interconnection ensures protocol comparibility.
CCP-R2	Device Management	CCP-C5.	With the features to on-board and de-board devices and connectivity with Fog, Edge and CLoud, the device management in addition to on-board and de-board along with provisioning, upgrade of devices and configuration can be managed.
CCP-R3	Data Collection, Analysis and actuation	CCP-C1, CCP-C2	System are interconnected and computing is distributed; with this the data collection, processing, analysis and actuation is possible.
CCP-R3	Scalability	CCP-C5, CCP-C4.	Each of the computing paradigms are scalable, which bring in scalability to computing, handling of added devices as well as computing of the increased volume of data.
CCP-R5	Security	CCP-C1.	Largely security will be a function of sofware application which is already enabled with the characteristics of interconnection and interplay.

- **Monitoring the Trash Bins:** Status of the bins can be determined by weight and/or by level of filling. Based on the level the action to clear the bins can be taken. Use Case 4 of CCP-IOT-RA may be considered for operations.
- **Monitoring the Soap and Water Consumption:** Soap dispenser and water faucets will need to have the sensors which can transmit the levels, and amount of consumption periodically. Use Case 2 of CCP-IOT-RA may be considered for operations.
- **Monitoring the Odour and Air Quality:** Air quality and gas sensors can be installed to monitor the odour and air quality to enable actuation of air purifiers or exhaust fans. Use Case 2 of CCP-IOT-RA may be considered for operations.

Salient features:

- Real-time notifications in case of cleaning requirements
- Collect Data from all systems for analytics
- CCP-IOT-RA enables notifications at all times

6.1.3 Parking Management System

Parking system is dynamic with the ingress and egress of cars along with detection of presence of a car in a particular parking space, to aggregate the numbers per parking level. Such data can be shown on a dashboard to ascertain the number of free and occupied parking spaces.

- **Car Entry/Exit Barrier Operation:** Sensors are installed to detect the presence of the car and movement (entry or exit) and based on the payment system the barrier is lowered or cleared for movement. All such sensors are required to be remotely monitored and can be automated as well. Based on the CCP-IOT-RA the Use Case 3 may be considered for operations.
- **Parking Spot Car Detection:** Presence or absence of a car at a spot and aggregation of such data levelwise can indicate the parking capacity situation. Sensors on each parking spot can provide that data. Data and location may be used to guide the car entering for parking to the available spot. Based on the CCP-IOT-RA the Use Case 2 and 4 may be considered for operations.

Salient Features:

- Real-time notifications in case of issues or assistance need
- CCP-IOT-RA required to ensure required notifications are sent in relevant use cases

6.1.4 A CCP-IOT-RA Based System

For the three systems, discussed briefly above, a CCP-IOT-RA can be adapted, tailored and deployed to enable all or more such sub-systems. In such a system, CCP-IOT-RA can enable:

- Addition of sub-systems, more features, and functionality like addition of monitoring of the air-conditioning system or Addition of specific fire safety (additional equipment) for newly added restaurants can be done easily with scalability and extendability of CCP-IOT-RA

Table 7: CCP-IOT-RA IoT Reference Architectures Evaluation - Challenges and Issues.

ID	Challenge/Issue	CCP-IOT RA mapping	RA Comments
CCP-IOT1	Data Volume, frequency and Processing	CCP-C4, CCP-C2, CCP-C3	CCP enables high volume of data collection, and processing as multiple paradigms and storage management is made available.
CCP-IOT2	Software System Architecture	CCP-C5, CCP-C1	With scalability, and interconnection and interplay enabled with fluidity of computing dynamic environments are easily served.
CCP-IOT3	Data Fusion and Dynamic Computing	CCP-C2	Data handling in IOT is crucia, and CCP-IOT-RA enables not only collection but processing of data across multiple nodes.
CCP-IOT4	Seamless and Multi-interface Connectivity	CCP-C5	CCP-IOT-RA is based on the multi-interface connectivity and leverages all means of communication.
CCP-IOT5	Fog/Edge Computing and Interplay with Cloud	CCP-C1.	Inherent feature of the way CPP-IOT-RA is designed.
CCP-IOT6	Choice of Computing Paradigms	CCP-C1, CCP-C3, CCP-C6	With an interplay possible, availability of computing paradigm is increased and the a decision can be made based on the policy and the context.
CCP-IOT7	Unified Model and Resource Allocation	CCP-C1, CCP-C3	With the way CCP-IOT-RA is designed, it functions as a unified system along with flexibility to allocate resources for various functionality in an IOT system.
CCP-IOT8	Integration and Collaboration	CCP-C1, CCP-C3	With the way CCP-IOT-RA is designed, entire system work on collaboration and synergy of the interconnected components.

- With interconnection and interplay, notifications, acutuation, and operational data, and alerts can be guaranteed for excellence in operations

6.2 Vehicle and Driver Behaviour

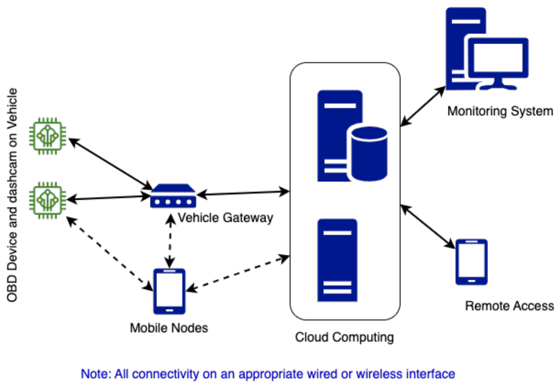

Figure 3: CCP-IOT-RA as applied to Telematics - Vehicle & Driver behaviour.

Fleets of commercial and passenger vehicles need to manage their drivers, vehicles, routes and schedules. In most cases, there is a daily plan, for say city bus fleet, transportation companies face dynamism in the way they operate. Monitoring vehicles, and drivers, is required to ensure compliance and safety, say hours of operation for drivers, and dash cameras for insurance claims. Various use cases can be considered which require real-time to near real-time information example: Accident or faults in vehicles will need to be reported in real-time.

Driver behaviour is analyzed based on the variety of data like speed, braking habits, and acceleration along with correlating the location of the vehicle. This data is collected regularly, and processed in batches to derive patterns, which provide a score for driving. The CCP-IOT-RA facilitates data collection, and ensures data storage, and processing on various intermediate nodes, which enhances the overall storage and processing capacity. This data stored on various nodes, can then to sent to central data store for storage and comprehensive analysis of driver behaviour. Alerts for issues such as speeding, lane changes, acceleration, and braking can be generated by processing the data either on the device itself or through a gateway (mobile or fixed equipment) within the vehicle.

Vehicle data can be collected for each trip, and an-

Table 8: CCP-IOT-RA Quality Attributes Evaluation.

ID	Characteristics	CCP-IOT-RA	RA Comments
CCP-QA1	Interoperability	CCP-C1	With interconnections and interplay, interoperability forms the central feature of CCP-IOT-RA for all components to work with each other, based on standards
CCP-QA2	Device Discovery and Management	CCP-C5	As on-boarding and de-boarding of devices is enabled in the CCP-IOT-RA enables device discovery and management as a function
CCP-QA3	Context-awareness	CCP-C1, CCP-C6	Context as defined for the topology of the connection or the application can be arrived at with the interconnection and interplay.
CCP-QA4	Scalability	CCP-C5	A base feature of CCP-IOT-RA and enables addition of devices and nodes dynamically.
CCP-QA5	Management of large volumes of data	CCP-C4	With multiple participating paradigms the volume of data can be easily managed.
CCP-QA6	Security, Privacy, and integrity	CCP-C1	Though a software feature interconnection and interplay is pivotal in enabling this.
CCP-QA7	Dynamic adaptation	CCP-C5, CCP-C8	With the way the system is designed for dynamic IOT systems, overall dynamism of any complex system can be handled, and the CCP-IOT-RA can adapt to the dynamics

alyzed over time to assess the need for maintenance or repairs, along with fault codes for diagnostics. Some use cases require the immediate transmission of fault codes, while others involve collecting data over an extended period to analyze operational efficiency, and performance in greater detail.

All these cases require the versatility and efficiency provided by CCP-IOT-RA. Its unique features of interconnectedness enable real-time alerts and notifications in the discussed use cases.

7 CONCLUSION

Using collaborative computing paradigms, a RA (CCP-IOT-RA), for dynamic IOT environments has been developed. The CCP-IOT-RA has been applied to two IOT system - building automation, and vehicle and driver behaviour. With this it is established clearly that a RA using CCP-IOT-RA will form a blueprint for design of solutions in dynamic IOT environments. Characteristics of CCP-IOT-RA has also been mapped to the characteristics and quality attributes of reference architectures, and to the challenges of IOT environments. With the available application it is evident that the CCP-IOT-RA is versatile and effective for IOT environments.

8 FUTURE WORK

Furthermore, there is a need to experiment, and apply the CCP-IOT-RA to applications in variety of domains. It is planned to detail the RA functional blocks and develop for target domains of building automation and telematics. By focusing on the quality attributes of the RA, which can enable studying the characteristics, attributes and performance of the CCP-IOT-RA further. In addition, compare and contrast with other reference architectures, based on the proposed RA requirements in this paper.

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