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MERGING ICN (INFORMATION CENTRIC NETWORKS) INTO IOT (INTERNET OF THINGS): A SURVEY

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Abstract
Internet of things gains a great hype in various environments from academic to industries in last few decades. The connectivity of each and every physical object to virtual environment internet creates great avenues for research. The growing number of the connected object raised the challenges in terms of heterogeneity, scalability, mobility and security and big data that they produce by following the host identification approach. In this regard new technologies have been proposed that qualifies these challenges in various environments. One of the adopted technologies is Information centric Network (ICN) - the technique that is integrated in IOT's. The target to integrate ICN in internet of things is to overcome the key challenges as it ensures the fulfillment of IOT's requirements. In this piece of work, we have deep analysis of ICN as integrated part of IOT's and also survey the related work to identify the methodologies that were adapted for the key factors of IOT using ICN frameworks.

INTRODUCTION

The paradigm where the internet is used to support the huge devices for their connectivity with their own methods to communicate has sponsored the new challenges of applications, protocol, and working technology. The deployment of cheap devices like actuators, sensors and other wireless technologies that support the wireless communication enable the large number of integrations of IOT's (Internet of Thing's), where most of the physical things lead to communication up to some level with some intelligence. Variety of solutions was proposed for the IOTs deployment with their applications. As so before IOT were deployed on basis of IP (internet protocol) that works on host base (Sheng et al., 2013) but this way doesn't supports the basic characteristics of IOT's, ICN was proposed as solution to this that ensures the availability of all characteristics of IOT's i.e. (Heterogeneity, mobility, interoperability, content naming etc.) (Lindgren et al., 2015) .

ICN is paradigm of content naming that enables to place the whole content at the midpoint of architecture(Vasilakos et al., 2015) instead to depend on the host identifier like in IP architecture. The major target is to integrate the internet into simpler and generic way for that multiple ICN instance were proposed. In 2009, instance if ICN i-e content centric networking (CCN) was proposed (Jacobson et al., 2009) which was then followed by number of multiple paradigms like (Netinf) network of information architecture (Dannewitz et al., 2013) .

Specifically Named data network is on in its hype because of if it simple configuration, scalability (Zhang et al., 2010). It provides the content naming strategy without focusing the physical arrangements and enables the best forwarding using routing scheme.

Now a days, ICN proposed new methods to tackle with the mentioned constraints and to strengthens the number of scenarios by taking advantage of its characteristics that enables the deployment of IOT applications in different environments i.e. Smart homes, Smart Health, Smart cities(Lindgren et al., 2015) . ICN also act as translator among the devices, it ensures the M2M (machine to machine) communications by supporting ICN with actuators, sensors. ICN is also proposed as the solution for gateways and constrained devices communication(Amadeo et al., 2016) . ICN integrated with NDN supports the efficient usage of energy in IOT environment, author(Hahm et al., 2016) has justified it by his research that it can reach to the level of 90%. Several researches have been proposed in a way to adopt ICN as a communication medium while having multiple properties i-e caching, routing, naming etc. (Lindgren et al., 2016) .

However the explored dimensions of ICN and IOT are restricted when we look for methodologies adapted for different scenarios. To the best of my knowledge this is first survey that provides the deep look into the IOT and its applications in different environment also to the methods applied for the satisfaction of different characteristics of IOT using ICN.

Through ICN technology IoT systems gain an improved data handling system that focuses on content delivery to improve both security and access efficiency. By handling content at network points ICN gives IoT devices better access to data and uses less data which saves their energy. The security system focuses on safeguarding data contents at the outcome level while defending against online dangers which strengthens the defense against modern cyber threats better than classic protection schemes. The Internet Computer Network lets devices move between networks smoothly while working with many different internet-connected things at home healthcare and industrial control systems. ICN builds stronger future internet of things networks thanks to how it makes data distribution better and extends system capacity.

2 Overview of Internet of Things

In 1999, Kevin Ashton coined the term internet of things (IOT) that emerged the new research directions. The goal of IOT is to deploy the huge number of devices that contain the set of components like sensors, actuators, RFIDs (radio frequency identification sensors) and smart phones. Such devices were capable of interacting with other object in a way to attain the common goal(Li, Xu, & Zhao, 2015) but the idea of IOT is changes as the time passes with the progress and new frameworks provided for IOT's. The IERC (IOT European research cluster) a research group defines the term IOT as: the mobility oriented network that have the self-configuration capabilities that resides on some specified protocols which contains several physical and virtual object having their identities, attributes, that uses intelligent interaction platforms and then integrate to the network.

Different technologies are proposed to implement IOTs on commercial level. These technologies include LPWANS, Information Centric Networks, Cellular (4G, 5G) and Lower power Short Range Networks. Here in this paper, I focused on Information Centric Networks (ICN) to implement IOTs. Herr we will discuss the primacy of ICNs to implement IOTs and the drawbacks of using this technology and future directions.

2.1 IOT Characteristics:

IOT base on the following collection of characteristics(Katsaros et al., 2014) :

• Inter-Connectivity:alongside IOT, every object or device can interconnect globally and can communicate.

• Object Related Service:IOT enables the object related services on the basis of constraints that were followed by the device such as the semantic and privacy consistency among the physical objects with their assigned virtual objects.

• Heterogeneity:IOT devices having different configuration on the basis of their hardware's, their form. Interaction among devices can be performed over different networks.

• Mobility:IOT devices can be mobilized which t=changes their status instantly. That may vary due to waking and sleeping, speed, roaming, connectivity or disconnection.

• Security: Security or privacy is one of the critical characteristic of IOT that must be considered while designing, developing the IOT devices as it may affect the real world. Also secure the terminals, infrastructure and the data transferred required security to transfer across them.

• Interoperability: it must allow other devices to connect and communicate in order to produce or consume information.

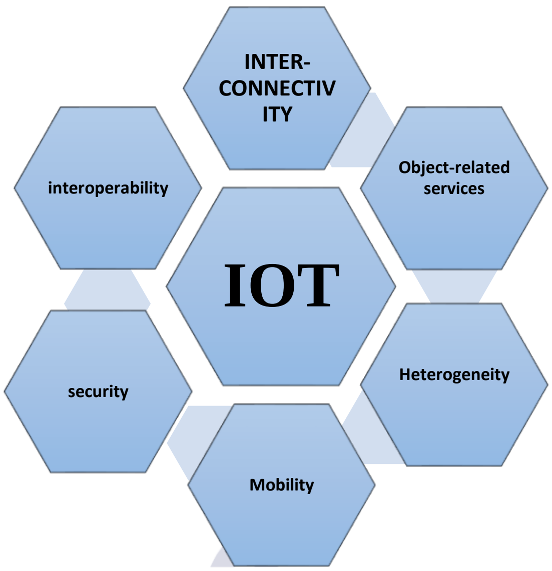

Fig. 1. IOT Characteristics

2.2 ICN features for IOT requirements:

As ICN is a framework that ensure the requirements of IOT's. ICN works in certain ways to satisfy these requirements as theses ways were described by Arshad ET AL (Arshad et al., 2018) in their work. According to that scalability, naming and addressing and energy efficiency can be achieved by in-network caching and content based security. Mobility and security can be targeted by Location independence, naming, content based security, receiver driven. Whereas Heterogeneity and interoperability can be tackled by using strategy layers and naming schemes.

3 Related work:

IOT's are now everywhere and are available for connectivity to anyone with limited characteristics of size, processor, and battery consumptions. But IOT are the digital model changes the concept of business, marketing, industry even to every field of this era. As these devices become cheaper, more and more devices were ready for connectivity. This growth of IOT may cause issues in the organizing, functionality management, and interactions. In this regard ICN (information centric network) is a paradigm that copes with the emerging issues of IOT by providing content oriented functionality in the domain of networking like caching, routing, naming flexibility, security, mobility. Without entertaining any other solution ICN is the best option for IOT services without having centralized entity as it ensures the problem solutions for IOT. ICN provides the way to access the content by name not including its location references due to which there isn't need any of hosts communication. In this manner when user asks for any content it will be provided by the nearest copy of that content from the server. For that network and application need to share the same namespace. Application of IOT is information hub which means that they contain full information. This will give us benefit for using of ICN transport. They want to see CCN which is called as "CCN lite" which will run on the sensor called as "contiki sensor" having very low processing and also with lesser space. We will use a new method which is very different from the previous one and we called it as method of adapting probing which is a method used for joining different data of the sensors and then send it to the data object which is called as CCN. This method gives us values which are totally new. Interoperability could be gain by the CCN and MQTT through a proper getaway. Their main point is to focus on ICN for communicating with the data(Ahlgren, Lindgren, & Wu, 2016).

3.1 Named Objects

Naming is the major concern of most of the studies for ICN typically flat naming, attribute based naming and hierarchical naming. Among which hierarchical naming is the most convenient and suitable naming scheme which is human friendly scheme like it can be readable, its partitions can be understandable, can be remembered for a time as it provide the content's semantic.ICN is design to make sure to provide more flexible and easy management of IOT gadgets. Lightweight named object (LNO) with backbone of NDN architecture solution was proposed that uses hierarchal naming not flat and also doesn't require bonding which enables dynamic environment for IOT.LNO[14] is a collection of named content and the functionalities facilitated by ICN with similar prefix of network, to attain an interface management for real "things". LNO provides the abstraction of real objects for discovery and management of virtual IOT' (Bracciale et al., 2019) .

ICN can improve the delivery of content by providing named content instead of terminals and named packets can be reused to provide in-network caching. Open cache a lightweight concept was proposed it terms of sharing regional cached data by advancing the hierarchical naming scheme. Open cache aggregates the hierarchical prefix instead of summaries of packet level for the reduction of collective cost of maintenance and communication. Open Cache can help in lowering the latency by providing data locally from the regional server's cache (Yang, Song, & Zhang, 2019), (Yang et al., 2019) .

Naming scheme also help in content discovery for the services. CCN naming schemes enable to provide right data and services to the right users. For that purpose content discovery based naming scheme was proposed that relies on the interest and the data packets propagation. This data could be delivering to the right person the provided three steps. In the very first step information create request for network. In the second step processing phase allots the actual services on the basis of naming and then in last step it deliver the content to the right users. But this mechanism doesn't follow the actual architectural rules of a ICN due to which is reliability in not very high(Labbi & Benabdellah, 2019).

3.2 IOT Caching

Although, caching is the foremost scheme for efficiency improvement in ICN for content distribution. Ongoing caching scheme are not as effective as it could be due to couple forwarding and latency network couldn't gain the scalability of throughput. TO cope with these latency issues ICN provides the roadmap of in-network caching that enables the termination of network caching redundancy. Likewise, the final decision was encrypted in the field of cache base of content packet in that way so it could easily be process and passed quickly to the router path with zero level of latency. It is necessary to passed packet quickly because routers or switches are not able to engage the huge traffic which may cause the bottleneck to the system. But this method's accuracy resides on the resulted decision, which can be gain by popularity ranking in lightweight caching. According to this mechanism the zero latency can be attain in two steps, filtering and decision making. Where filtering is done at the switch end for quick forwarding and time consumption whereas decision potential is locate at the storage terminal to evaluate the performance of caching schemes. For such strategies ICN routers were specifically designed for the forwarding and caching which are core functionalities of ICN. Forwarding carry the content packets to the node and the caching hold the most popular content is its memory for the specific duration(Yang et al., 2019) .

Important factor as far as the reliability and the speed of the delivery of the content is concerned; the uniqueness of the content of the cache which is at many points within the network is also an important aspect of it. But in environment which is fully constrained in IOT, we have memory which is called as a resource fully scarce. This means to say that how we can use the particular memory which is available to us for caching. From the past research we will come to the point that caching which will get network topology has big concerned with it. ABC is introduced which is known as "Approximate between Centrality" that will use the heuristic which is fully topology based according to the current strategies. But this will not give any knowledge about the network and no overhead of communication. They will match this strategy which is totally new with many ICN strategies for caching and will also estimate effectiveness with the help of IOT devices in big test bed. Their result will be more cost efficient than those which have much expensive strategies (Pfender, Valera, & Seah, 2019). .

IOT will not scales good in IP (internet protocol) as compare to ICN models. NDN which is called as "named data networking" will gives us some features of applications of IOT. This includes forwarding which is state full, caching, data assurance which is already built in. framework of NDN is introduced, which will not have link with routing and secure on boarding. Mainly the rapid increase in demand of the IOT likewise in smart cities which will have need of scalability which is very high and will thus create a problem to NDN routing.

Here they are come up with NDN (IOT) which they called as NDNIOT which is a framework (lightweight) use for routing and authentication. They also come up with NS-3, which is a type of simulator which shows us that the desire framework is scalable. This will supports approximately 40 thousand nodes per kilometer square with time of about 250 sec and will have very low overhead of approximately twenty kilo bites as per node. This will show us the high trend of IOT in applications like smart cities(Mick, Tourani, & Misra, 2017) .

We know that IOT devices will show us the unique aspect of the operations in networking. Issue related to IOT which is mainly due to communication pattern which are very complex and also different topologies and force which is for security to think about the operations in networkingwhich are basic in nature are doing in an accurate way. Also the IOT will come up with some limitations of IP based model for supporting the applications which are content based and the growing tends of the ICN will likely complaint with the vision which is given by IOTs. They will give a strategy which is light weight in nature and a forward based strategy for NDN on "IEEE802.15.4" NDN is architecture of ICN. The strategy which is basically a forwarding strategy that will less the overhead on the network in order to minimizing the bare by keeping performance which is good in IOT applications. Without having the address of the node and in order to forward the contents, this strategy is made on technique which will give an correct forwarding with less overhead(Abane et al., 2019) .

3.3 IOT Security

This distributed caching also help out to make the data secure. IOT are mostly defined in term of that IOT are the interrelated sensing and actuating devices (Yang et al., 2019) that are used to share data over the platform using merged framework (Wang et al., 2019) . That information could be public or private which can be authenticated by the central framework. As we believe in distributed caching for ICN, we can use its energy and determine the feasibility to store the authenticated certificate. This can make secure to our data either that is private or public. By using distributed caching technique CCV protocol was design to make the data secure by holding a model that evaluates the trustworthiness of the devices. CCTV protocol helps in efficient energy utilization and fast locator for certificate holder (Wang et al., 2019) .

Sensors are also being used for the purpose of monitoring and also actuators the accurate actions in terms of failures or some fault in the system. As with the advancement of IOT controllers will connect these devices with the local networks that have a low wireless power and these things are connected with each other through a source like a cloud which will then connect to the internet. Actuators and sensors which are connected with each other are mainly focus on connecting inter-networking industry in a secure and safe way. The efficiency of ICN that will give a secure and safe networking solution for the systems that will place in the industry in a controlled environment. They are also focusing on sensing the dangerous gas that will come out from the industry environment from refineries and are match them with IP based mechanism like "MQTT and CoAP". Their result will show that content security models which are centered in nature and also DoS resistance are the main reason for the placement of ICN in IOT industry which is very critical in nature (Frey et al., 2019) .

As the privacy and security is one of the problematic challengers for IOT networks because of its open source communication which is basically wireless, that includes networks like VANETs. Different characteristics that will include requirement scalability, environment which is out of control, resources which are constrained, heterogeneity all these things create the problem of security and privacy more complex. Also the integrity of the date and confidentiality of the data may also affect the need of availability. While doing the data routing the threats which are performed is related to security while performing the operations. So designing a routing protocol which is fully secure is a challenge. This paper give us a design for light weight algorithm which is related to security and named as NDN that will give the IOT applicable for already built in assurance for the provenance of the data. So, a unique framework for the security named as NDN based NCARP protocol is introduced (Thigale et al., 2019) .

IOT's provide the efficient networks which involves the challenging features of scalability and efficiency. Researcher works on the modification of ICN based Network. As the ICN have the basic feature for communication like "naming of data-which is advantageous but still have challenge that naming exceeds the data size, "Caching-reduce latency but its challenge is that it is not useful when object request at the most once etc.

Proposed architecture overcome these challenges in different ways like distributed caching concept is introduced, Decoupling is used to cater with mobility where security issue is introduced due to this. As for security purpose ICN is content oriented rather than hosts. Solution for security is object security which secures the communication channel among the nodes. But Naming of data is not suitable when there are billions of devices and also when they continuously accessing. Decoupling is not applicable when authentication is require for management (Lindgren et al., 2016) .

3.4 IOT Interoperability

IOT's are making efficient to fulfill the future need in accordance with internet. For that purpose number of architectures was proposed to tackle with the challenging issues. IOT's are now available everywhere concepts to other at any moment at any place. These devices are not of same domain their capabilities and responsibilities are not synchronized. They require interoperability a certain levels. As when we talk about the interoperability at network layer IOT's are using low power consuming protocols whereas object of physical world uses efficient protocols for solving interoperability we need standardization at this level. Messaging protocol interoperability- protocols are used which have their unique characteristic for communication in accordance with their device capabilities. Require solution that helps to build linkage semantically and seamlessly. Data annotation operability-traditional data provided by sensors is random and raw with some metadata which is provided to software agents. To deal with all the interoperability issues, we need third party for communication i-e gateway. Semantic gateway is proposed which cope with these challenges. It provides an interface for by integrating the messaging and the data, beside that third party services are used to tackle the heterogeneous sensors to extreme level abstractions. Nodes of gateway have limited computational capacity so for that Semantic Gateway as Service (SGS) is used among nodes and the IOT services of semantic Gateway.

As Service (SGS) have three cores. Multiprotocol proxy-this faces the real world objects-when sensor observe and generate data device pass that observation to SGS as a POST message. Semantic annotation-its process the Posted message received from sensors, domain specific services are identified before forwarding, description, observation at this core. Gateway services: it provides the knowledge of high level from raw data of sensors Before this the architectures which were proposed are applicable in vertical(sensors, gateways, service and applications)which is not efficiently operational in term of operability the proposed concept works horizontally among the nodes. Protocols of IOT that are well known i-e CoAP and MQTT are group in single gateway SGS. Semantic gateway lies between the sensors and cloud servers which helps in the translation. Mostly used, MQTT, XMPP, andCoAP protocols, for designing their semantic part reliable and smooth. But Computational unit if IOT require up gradation for the proposed architecture which is quiet difficult and may leads to new challenges. Large amount of messages were passed from gateway for posting and ending and we have read the gateway have restricted computational power so it cause issue while there is pool of clients (Desai, Sheth, & Anantharam, 2015).

As we know that the problem of interoperability is cause due to communication of protocols heterogeneity on IOT. Nodes of the different sensors contain different arrangement with one another. As in the environment which is cloud based, all the nodes which are known as sensors node will allow to transmit information by using the protocol of their own choice for communication with the application of IOT. The combine information is not restricted to specific device which is basically a senor. Here we have a middleware which is able to do tasks with protocols which is actually a bond amongst application of IOT and sensors node and it will be a good approach for solving a problem of interoperability.

The study will introduce a middleware which is actually a cloud based and which also give us platform for communication. This communication give us interface which is able get the data from the node sensors which are "CoAP" and" Resrful". The data that we will get will stored in an IOT based mechanism of storage which is actually "NoSQL" database. For the purpose of different testing and experiments they will use methodology for testing which Interoperability methodology. The end result will give us an idea that middleware is able to get information from each of two protocols. All the information that we will get will stored in the form of unstructured or structural data on IOT information storage (Pramukantoro & Bakhtiar, 2020) .

In order to meet the up growing demand of IOTs and meet their requirement, certain different standards, protocols are added in industry and research. As we know that the emerging up gradation are also reliable with one another. These are built under the supervision of specific criteria for domain without involving independent environment of domain. ToT setup is a time taken work which is manual in nature for the integration of components which are heterogeneous in nature. The gap in the interoperability within the parts of IOT will presented in different ways in past.

The study will proposed a unique path to interoperability of IOT which works on "DRL". They presented algorithm of DRL that will used the architecture of network which will work on "NLP". NLP is used for learning the complicated tasks having the data representation like XML etc that are commonly use in internet of things. The proposed approach will worked in a way from end to end which will not required any manual work (Klöser et al., n.d.) .

Interoperability of the data is the main hurdle in the innovation of IOT. The study will give us recent development on interoperability on IOT which will then extends to the requirement which will behave as a principle design for the solution of interoperability. In order to reduce the space gap between the social media and IOT, certain standards are includes which are namely as "NGSIv2" and API by which it will help in communication with physical system which are cyber based.

For the detection of fire in early, certain data from the different sensors collected and then this data communicate with each other in order to detection the fire early. The result will show us the by maintaining the low interoperability of data weight which is light and also first plug and play methods will give a service to our society in a good way (Kalatzis et al., 2019) . The devices of IOT are upgraded in terms of volume based as well as heterogeneity which is use in different domains of application. All these things will disconnected and the information come from all these are not accessible to these applications. One of the reasons is lose of interoperability which is holistic in nature. Many studies are going on it but all will give concentration isolation in level of interoperability. This study will proposed a hybrid approach which is a unique approach which will present cognition in IOT(Adesina & Osasona, 2019) .

As we know that the interoperability amongst the types of platform is the space to fill for IOT. Recently the solutions which are being proposed are work for static interoperability that will come from service based web environment that will not come into place with the ecosystem of IOT. The main reason for these unchanging approaches will come from the problem with scalability which is not applicable for big devices like IOT. This will give indication for going to a dynamic approach that will use systems of IOT that will make them intelligent and self aware. Introduce a intelligent architecture which is also self aware as well will help in solving the problem of interoperability (Kramer & Haehner, 2019) .

In IOT, interoperability has much more importance and the reason behind this importance is its communication protocols with different type of data. Different models which are being introduced which are used in order to meet the requirement of interoperability. But all these things are come into place on base of scale which is hierarchical in nature, A very unique approach will presented that will use in order to measure the interoperability through a scaled metric quantity. Distributed system will involve when we will consider them like IOT where they will interoperable different messages. Under the certain condition, the message which is being changed as calls and will show us likes a model. This model will help us in order to quantify the behavior of interoperable messaging (Kotstein & Decker, 2019) .

Millions of devices are connected with each other that requires identifier which distinguish it from others, and enables the users to identify object easily. For that purpose number of Frameworks was proposed by the researchers where every device used different framework which causes heterogeneity issue. To overcome this issue author proposed named semantic code-S based on semantic framework. It provides the base for each Identifier so that different frame work objects works autonomously, this really supports the heterogeneity issues effectively (Li, You, & Chen, 2019) .

To provide peer connection to the objects a full fledge framework of protocols is required. But the diversity of these protocols causes issues in connectivity and interoperability. In this paper protocol intermediate is proposed that is fully synthesis that works for the connectivity of heterogeneous objects. The proposed stack is based on DEX-Data Exchange that provides the way to IOT to connect seamlessly by mediators (Bouloukakis et al., 2019).

4 IOT ICN Architecture

ICN (information Centric Networking) which is currently grow as a upcoming architecture which main motto is to high the demand for distribution efficiently and for greater scalability. So, from going away from models which are communication models and are fully reliable on host addressing, caching, communication which is multiparty and at last the models which will combine the receiver and the sender together. This mechanism is very efficient in various dimensions for outperform internet protocol. Apart from the content, the high demand for IOT with its many challenges which are currently on the internet will show us the growing demand in terms of performance of ICN. Mainly CCN architecture which will have a lot of contribution in IOT likely in the form of use of bandwidth and also in energy utilization. As far as by mainly target the main requirement for IOT, comparison of CCN and IP will leads to CCN which is more energy efficient and use less bandwidth and will also solve the problem of ICN caching (Quevedo, Corujo, & Aguiar, 2014).

The growing trend in the IOT creates a lot of challenges in the network field related to network design. It will be predicted from the current situation that the upcoming IOT devices will give their concentration on data sharing which is service oriented apart from data collection which is purely point to point. Different requirements that will fall under this likely as mobility, security, diversity in the form of communication will also upgrade itself by the new trends which includes different communication patterns. As the current IP networks give its concentration on specific places and channels which are point to point. The difference between these two which mainly include functionality and requirements which are dynamic are inefficient. Focus diverted from information of specific place. This all will follow by the IOT communication when type of information will be called as a service. This article gives the example of mobility which will identify the scope of ICN in IOT. Also this paper will also show that the architecture will fulfill all the requirement followed by the IOT communication. XIA and NDN these are the some architecture which is being used by the ICN (Chen et al., 2016) .

Data is the heart of IOT. Various techniques were proposed for data sharing and processing like named data, data centric, which works very efficiently. The core of these techniques doesn't require any change. But Virtual state layer was proposed which works on to splits the data and logic units. It integrates the data centric along with knowledge factor to manage the data on the basis of amenities. This provides the data unit VSL interaction directly to the programmers.

That leads to overcome the problem, data modeling. This model works on four layers. First layer is the hardware equipment. Second layer provides the physical connectivity between nodes via knowledge agents. Third layer is an interesting layer which is proposed layer works on semantic discovery. And the top layer provides the services. The proposed layer uses the peer-to-peer approach for routing[14] of request to permits a constituent to available layout. As in network devices are of different domains there are certain issues of connectivity, processing, computation power among those devices when they ask for services. These issues were not tackled in the proposed architecture. Devices connections are not reliable in prospects of proposed model (Pahl & Liebald, 2019).

Key challenge for IOT's is to determine the services which were provided by a particular server where all the hardware are involved. Architecture like IETF, REST (Representational state transfer) which work efficiently in network and constrained services devices. In IETF architecture Look up interfaces and resource registration are specified to RD (Resource directory) with determined link formats. Where RD is defined in database which keep the links regarding to resources provided by EP-known as RD entries. EP is a core server with associated schemes with their context.

The REST interface for EP registration, maintaining the RD Entries, lookup of resources are provided by RD. this work efficiently but have many drawback and issues of low scalability, connection efficiency, latency, single point failure due to centralized architecture. In this paper

researcher proposed decentralized ICN based architecture.

In the proposed architecture RDs are deployed in distributed order to network components. IOT resources can be registered to Router RD by an EP in distributed architecture. After the acceptance of registration by Router RD, the resources are tagged with unique identifier named URI .In this architecture IETF s realigns in prospects of RD. But in distributed Rd router does not maintain the routing table for each resource but on aggregate resource.

The tables and resource advertisement are triggered by the update which specifies to client that how many resources would be allowed. The purposed system works very efficiently as it reduces the router overhead. That router does not maintain the router table on the basis of services but maintained on the basis of attributes of IOT resources. Also overcome the issues of scalability, latency, congestion, availability. Router is capable f to have overview of resources on the basis of client's requirements. Connection among the services is not reliable as the router table is not maintaining the table for each service. Number of RD increases as the number of clients increases so it leads to complexity as the network is getting mature (Dong, Ravindran, & Wang, 2016) .

5 IOT Applications

There are different service which are provided by Internet of things in order to connect the devices which are multiple and heterogeneous in nature. A large amount of different applications domain will be covered by these devices.

The growing trend in the smart objects and their everywhere availability will make the life easy (Atzori, Iera, & Morabito, 2010) by presenting various applications. In order to provide the new applications, various domains support the technologies related to internet of things. Here the four main applications we have which will have high impact on the internet of things and that will include.

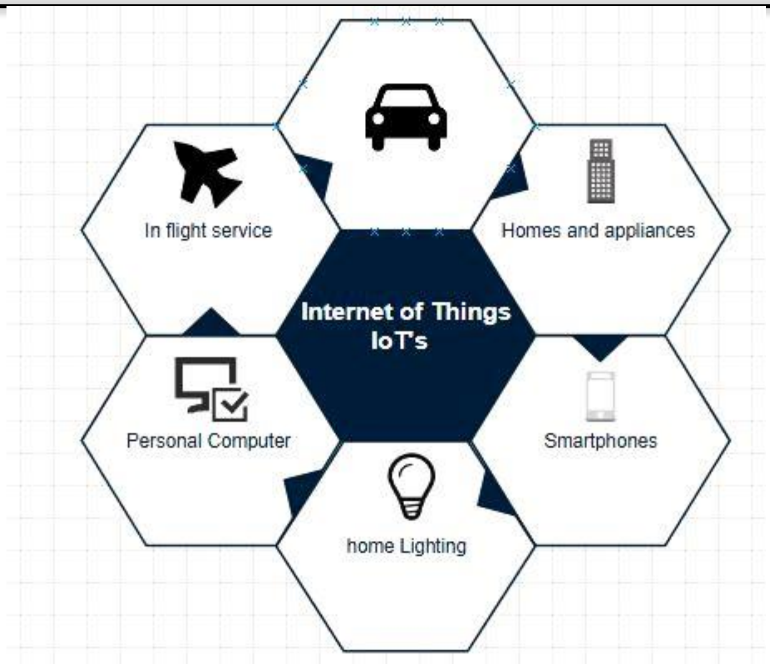

Fig. 2. IOT Applications

5.1 Healthcare domain

In the healthcare field there are various benefits of these types of internet of things related technologies. With the help of different sensors, we can detect the patient health automatically and then the report is send to the doctor for treatment. In this process there are some of the tasks which will perform and these are (Amendola et al., 2014):

➢In the emergency case, detection of the movement and the location of the patient for giving a fast access for treatment of the patient.

➢Controlled different accidents which are harmful and also reduced the different incidence in future. Authentication and identification is very helpful in this way.

➢In order to save the time, the collection of the data will be automatic.

Patient status will be detecting on the basis of different sensors.

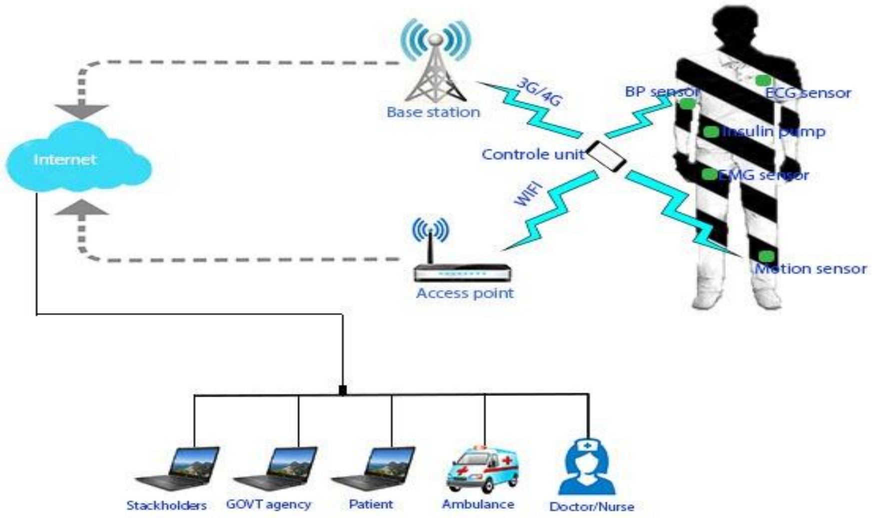

Fig. 3. Application Scenario of the Healthcare model

5.2 Smart environment domain
This will include our offices, home and plant. Smart environment focus on the environment which is comfortable and fully equipped with embedded objects which are intelligent based objects mostly used in industries, offices, houses and different entertainment places etc. With the help of different technologies which are known as "RFID technologies", smart houses can equipped themselves with these embedded objects. This will create the different intelligent based services for home which will include cooking, less consumption of energy, shopping, washing programs and early healthcare (Darianian & Michael, 2008).

5.3 Logistics and transportation domain
This will include different buses, cars, trains and bikes and also all those different means of the transportation which are fully sensors equipped. In order to fully monitored and analyze different operation related to management, sensors are being used in transport goods for this purpose (Zhang, Yu, & Zhai, 2011).

5.2 Social domain
This will include different application that will help the users to communicate with one another for their relation building. So, here we are notifying some social network (Smith et al., 2015) . Application of internet of things in personal network as well as social networks which will include LinkedIn and Facebook, which will allow different peoples to remain connected and also in touch with the world. Currently the social and personal domain is on trending and this is because of the most of the tools which will depend on internet of things.

6 IOT Applications with ICN
There are different ways which are combing with ICN and IOT and this will be presented in the literature. Here we will categorize them on the basis of four domains application which will include smart houses, smart health, smart building, and smart grid.

6.1 Smart Grid
The past worked which will support ICN in different small grids are in trending. This will be justified because of the benefit of the ICN which is used in domain for application. In order to give support of distribution to the data, ICN will be included in the infrastructure of the intelligent network. Broadcast nature of the smart grid is fully rely on multicast, because one node can transmit data to the many others nodes that will show us the need for infrastructure which is fully suited to communication. By the help of this ICN paradigm, we are able to support the different communication amongst different types of entities within the network.

In the literature, "C-DAX" (Cyber-secure Data and Control Cloud Consortium, 2014) will provide us a platform for the large amount of smart gird application. C-DAX will base on different types of properties in order to support the architectures of the network which is flexible, resilient, secure and more scalable then the conventional system for information [43]. It is also based on the some requirements of SG in order to give the base for the large integration of energy which is reusable. Also more benefits for different type of utilities will be given to the set of the heterogeneous SG. Different components which will include different type of electric vehicles and energy distribution resources will be support by the ICN in this case.

Capability of the ICN for the integration of the SG will come to us from "rendezvous point" which is a kind of approach used for the sending date to publisher and processing and storing the date will be occur there. Multiple RP is responsible for the management of the data. In a situation where every publisher which will publish different topics and will also announced data on RP, whereas the subscriber will also connected with all the sets of RP (Katsaros et al., 2014). While in order to focus on infrastructure of the network, the approach which is based on the ICN is helpful in adopting the capabilities of the smart grid. This is also very helpful in communication technologies which are selective and will also good for the some of the requirement of application.

- The findings which are come to the researchers will show that ICN is capable of addressing different types of challenges related to emergency that will also come to the design for RP which is multi RP used for the processing and selection of the networks. In order to focuses on characteristics topology of network in the country named as Netherlands, will show that the capability of

the approach of ICN will handle the above all the challenges via experiment which is simulation based.
Currently, C-DAX is a use case in the real world which will include substations distribution at IEDs end, MV level deployment and energy transactions which are retail in nature (Cyber-secure Data and Control Cloud Consortium, 2014) .
Home networks are the next case in smart gird ICN. Our home network which is also known as "HOMENET" will do many functions which include control of climate, lighting, sharing of media, and management of energy within the environment of the grid. So, we have the different requirement for the traffic network, control, mobility and security. All these hurdles are related to the main questions which is network which is IP based will be prioritize (Yu et al., 2016) .

6.2 Building and Home Automation

Here the main discussion is on ICN integration in smart building and houses because they are belonging to the same two domains. They all relay on the IOT for the controlling and monitoring of the homes. Different devices which includes door locks, switches which are wireless, cameras for security, different types of sensors and thermostats which are smart in nature are presented to the market for the customer in these recently years. Approximately 50 – 100 million connected things are led by IOT. A lot of research is being required for coming to the specific platform which is able of recognized this brand new idea.
Researchers will come to the point of having a paradigm for ICN which solve the problem of communication for the smart houses (Mick, Tourani, & Misra, 2017), (Quevedo, Corujo, & Aguiar, 2014). In order to provide the ICN data, routing is being used which is multicast. Also, this will provide help for the developers a high flexibility on the basis of the security. There is a lot of work done by the researchers on the ICN in IOT. The different requirements for smart houses by ICN will be discuss as follow:

- **Wireless network:**

with the help of the technologies related to the wireless will show us the new opportunities about flexibility. If application will need reliability, there is a need for the design of the scheme for the transmission.

Security: information which is sensitive is also tackled by the application for the smart houses and that will required authentication, integrity and confidentially features. This data will be requested by many users within different location and administrative domains.

- **Services models:** we have two models for services in smart houses which are pushing and pulling. Push service handle transmission of data which include sages and alarm messages. Pull services cover a big range of application which are controlled, where action for the enforcement is needed and also the monitoring the collected data where needed.

- **Multi Communications:**

There are at least four transmission modes which will include one single source and a single customer, many sources and single consumer, multiple consumer and source which is single, multiple of consumers and also the combination of these "1C: MS and MC: 1S".
NDOMUS [45] is an architecture which is NDN based and was presented within the scenario of smart houses. Basic component of NDN include communication for strategy, model for service and naming scheme.

6.3 Smart Health

Application which is based on the internet of things will reduce the total overload when people are using the services, everywhere and anytime (Kumar et al., 2017) . In these application where the exchange of the data is fully based on IP will procedure the issue related to mobility, privacy, vulnerabilities which are related to the security. Architecture which is ICN based will proposal in NDN which is an approach that will use the content naming for the delivery of the data. NDN is used in the different projects for IOT healthcare applications are as follow:

- Apart from the model which is client server based on IP addressing, NDN will provided the access using naming by model which is peer to peer. That is why the there is no need of translating the naming data to the IP addresses that will increase the efficiency and will reduce the overload on the system.
- Failure of the node is reduced by the distribution of content amongst hosts which will do the load balancing.
- Mobility is supported by the NDN which will then good for the patients which are mobile. Data security

is tackle by NDN apart from channel security (Kumar et al., 2017) .

- By the help of the encryption, NDN will enable a good control for the access.

NDN in ICN, provide a good environment for support to the security of the data and mobility of the user by the help of naming in order to know about the location.

6.4 Smart Transport

ITS which is known as the transport system which is intelligent in nature is one of the basic component of smart city. Information sharing to all the devices which are connected in order to provide the services to the consumers. Consumers focus on the little information about the supplier's identity and location. Most of the time the communication will occur on the motion usually when the consumers are moving for the data. Recently the ITS have architecture of IP based and are act as a medium of communication between the devices which are not deliver the mobile content effectively and will cause problems like evolution, intermittent connectivity and allocation of not efficient IP addresses.

7 Comparison of the ICN IOT Applications

In order to find out the ICN role in IOT, we presents the comparison between the characteristics related to ICN with application domains

Table.1 Comparison of the application of IOT domains about the features of ICN

Category	Naming Strategy	Security Measures	Service Model	Routing Mechanism	Mobility Support	Caching Strategy
Smart Transport	Naming scheme to inquire about road conditions for passengers	Content security rather than encryption	–	–	–	–
Smart Home	Two namespaces: one for tasks, one for management	–	Multi-communication adopted	–	–	–
Smart Building	Naming strategy is used	–	–	PIT accepts requests	–	–
Smart Health	Healthcare services located using NDN	NDN algorithm used	–	–	End-user mobility supported	–
C-DAX	–	Secure data separately from communication channel protection	RPs allow data transmission to subscribers	Paradigm for subscription-based services (C-DAX)	Supports mobile customers	Data cached at each intermediate node
HOMENET	–	–	–	–	–	–
Smart Grid	–	–	–	–	–	–

8 Challenges Addressed by Integrating ICN into IoT

Bringing ICN into IoT network architecture solves significant problems to make IoT more secure and faster. ICN technology solves these major problems for IoT networks.

- **Scalability and Naming Management**: The typical IP network shows weakness handling large numbers of IoT devices. The ICN system lets us find content items directly by their properties while getting rid of traditional address systems.

- **Security and Data Integrity**: Through its design ICN offers direct protection to each content object without needing secure network links for defense. Named IoT data benefits from online security and stays protected against unauthorized users in fast-changing systems.

- **Efficient Mobility Support**:
The system supports easy device movement because Internet Content Networking ignores physical location when providing access to content. Mobile IoT applications benefit from better data availability and higher reliability when this system is used.

- **Improved Quality of Service (QoS)**:
ICN technology delivers high-quality service to real-time IoT applications through better data accessibility and faster processing that reduces packet loss.

Seamless Interoperability: ICN
supports multiple access technologies and protocols, enabling interoperability among heterogeneous IoT devices and improving connectivity across different network environments.

9 Future Dimensions

• Further work is needed to enhance the coupling of IoT and ICN architectures, especially in the 5G network environment.
• The presence of a massive number of diverse devices with varying requirements and characteristics makes integration complex.
• ICN has significant potential in 5G networks by facilitating seamless coupling of IoT devices with cloud computing platforms, core networks, and access networks.
• Challenges remain in achieving seamless "information-centric" coupling while addressing mobility, security, and Quality of Service (QoS) requirements.

10 Conclusion

The paper will present the overall broad overview of different characteristics of ICN and IOT. After this the advantages of using the features of ICN will be reviewed which include caching, mobility and naming. The current research work on the IOT and ICN will be indentified in this paper which is applied on multiple environments that include smart grid and smart houses etc. in order to emphasized on ICN contribution in the particular area, we come to the conclusion that the work which is related with ICN in the domain of IOT is not restricted to the particular application. The proposed work will show us to improve the security, mobility and performance of these applications as well as to explore the more characteristics of ICN. This paper will show us that ICN is useful in order to convert the communication which is IP based in IoTs while emphasis on content apart from node identifiers.

REFERENCES

1. Sheng, Z., Mahapatra, C., Zhuang, W., & Leung, V. C. M. (2013). A survey on the IETF protocol suite for the Internet of Things: Standards, challenges, and opportunities. *IEEE Wireless Communications, 20*(6), 91–98. https://doi.org/10.1109/MWC.2013.6704478
2. Lindgren, A., Ahlgren, B., Abdesslem, F. B., & Schelén, O. (2015). *Applicability and tradeoffs of information-centric networking for efficient IoT*.
3. Vasilakos, A. V., Li, Z., Simon, G., & You, W. (2015). Information centric network: Research challenges and opportunities. *Journal of Network and Computer Applications, 52*, 1–10. https://doi.org/10.1016/j.jnca.2015.02.003

4. Jacobson, V., Smetters, D. K., Thornton, J. D., Plass, M. F., Briggs, N. H., & Braynard, R. L. (2009). Networking named content. *Proceedings of the 5th International Conference on Emerging Networking Experiments and Technologies (CoNEXT '09)* (pp. 1–12). ACM.
5. Dannewitz, C., Kutscher, D., Ohlman, B., Farrell, S., Ahlgren, B., & Karl, H. (2013). Network of information (NetInf)–An information-centric networking architecture. *Computer Communications, 36*(7), 721–735. https://doi.org/10.1016/j.comcom.2013.01.009
6. Zhang, L., Afanasyev, A., Burke, J., Jacobson, V., Crowley, P., Papadopoulos, C., Wang, L., & Zhang, B. (2010). *Named Data Networking (NDN) project* (Technical Report NDN-0001). Xerox Palo Alto Research Center (PARC).
7. Amadeo, M., Campolo, C., Quevedo, J., Corujo, D., Molinaro, A., Iera, A., Aguiar, R. L., & Vasilakos, A. V. (2016). Information-centric networking for M2M communications: Design and deployment. *Computer Communications, 89*, 105–116. https://doi.org/10.1016/j.comcom.2016.03.015
8. Hahm, O., Baccelli, E., Petersen, H., & Tsiftes, N. (2016). A named data network approach to energy efficiency in IoT. *2016 IEEE Globecom Workshops (GC Wkshps)* (pp. 1–7). IEEE.
9. Lindgren, A., Abdesslem, F. B., Ahlgren, B., Schelén, O., & Malik, A. (2016). Design choices for the IoT in information-centric networks. *2016 13th IEEE Annual Consumer Communications & Networking Conference (CCNC)* (pp. 882–888). IEEE.
10. Li, S., Da Xu, L., & Zhao, S. (2015). The Internet of Things: A survey. *Information Systems Frontiers, 17*(2), 243–259. https://doi.org/10.1007/s10796-014-9492-7
11. Katsaros, K. V., Chai, W. K., Wang, N., Pavlou, G., Bontius, H., & Paolone, M. (2014). Information-centric networking for machine-to-machine data delivery: A case study in smart grid applications. *IEEE Network, 28*(3), 58–64. https://doi.org/10.1109/MNET.2014.6843231
12. Arshad, S., Azam, M. A., Rehmani, M. H., & Loo, J. (2018). Recent advances in information-centric networking-based Internet of Things (ICN-IoT). *IEEE Internet of Things Journal, 6*(2), 2128–2158. https://doi.org/10.1109/JIOT.2018.2873343
13. Ahlgren, B., Lindgren, A., & Wu, Y. (2016). Experimental feasibility study of CCN-lite on Contiki motes for IoT data streams. *Proceedings of the 3rd ACM Conference on Information-Centric Networking (ICN '16)* (pp. 225–226). ACM.
14. Bracciale, L., Loreti, P., & Bianchi, G. (2019). Lightweight Named Object: An ICN-based abstraction for IoT device programming and management. *IEEE Internet of Things Journal, 6*(3), 5029–5039. https://doi.org/10.1109/JIOT.2019.2894462
15. Yang, Y., Song, T., & Zhang, B. (2019). OpenCache: A lightweight regional cache collaboration approach in hierarchical-named ICN. *Computer Communications, 144*, 89–99. https://doi.org/10.1016/j.comcom.2019.05.012
16. Yang, Q., Wu, J., Zhang, Y., & Li, X. (2019). An almost-zero latency lightweight mechanism for caching decision in ICN content router. *2019 IEEE 38th International Performance Computing and Communications Conference (IPCCC)* (pp. 1–8). IEEE.
17. Labbi, M., & Benabdellah, M. (2019). CCN Context-Naming for efficient context-aware service discovery in IoT. *International Conference on Mobile, Secure, and Programmable Networking* (pp. 1–12). Springer.

18. Pfender, J., Valera, A., & Seah, W. K. (2019). Easy as ABC: A lightweight centrality-based caching strategy for information-centric IoT. *Proceedings of the 6th ACM Conference on Information-Centric Networking (ICN '19)* (pp. 1–11). ACM.
19. Mick, T., Tourani, R., & Misra, S. (2017). LASeR: Lightweight authentication and secured routing for NDN IoT in smart cities. *IEEE Internet of Things Journal, 5*(2), 755–764. https://doi.org/10.1109/JIOT.2017.2725238
20. Abane, A., Daoui, M., Bouzefrane, S., & Banâtre, M. (2019). A lightweight forwarding strategy for Named Data Networking in low-end IoT. *Journal of Network and Computer Applications, 148*, 102445. https://doi.org/10.1016/j.jnca.2019.102445.
21. Wang, M., Zhang, Z., Liu, Y., & Qian, H. (2019). Collaborative validation of public-key certificates for IoT by distributed caching. *IEEE INFOCOM 2019 - IEEE Conference on Computer Communications* (pp. 1–9). IEEE.
22. Frey, M., Gündogan, C., Kietzmann, P., Lenders, M., Petersen, H., Schmidt, T. C., Shzu-Juraschek, F., & Wählisch, M. (2019). Security for the Industrial IoT: The case for information-centric networking. *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)* (pp. 1–6). IEEE.
23. Thigale, S. B., Patil, A. R., Patil, P. A., & Patil, P. S. (2019). Lightweight novel trust based framework for IoT enabled wireless network communications. *Periodicals of Engineering and Natural Sciences, 7*(3), 1126–1137.
24. Desai, P., Sheth, A., & Anantharam, P. (2015). Semantic gateway as a service architecture for IoT interoperability. *2015 IEEE International Conference on Mobile Services* (pp. 1–8). IEEE.
25. Pramukantoro, E. S., & Bakhtiar, F. A. (2020). Cloud-based middleware for syntactical interoperability in Internet of Things. *Journal of Information Technology and Computer Science, 5*(1), 32–37.
26. Klöser, S., Rieger, P., & Mietzner, R. (n.d.). *Deep reinforcement learning for IoT interoperability*.
27. Kalatzis, N., Avgeris, M., Dechouniotis, D., Papadakis-Vlachopapadopoulos, K., Roussaki, I., & Papavassiliou, S. (2019). Semantic interoperability for IoT platforms in support of decision making: An experiment on early wildfire detection. *Sensors, 19*(3), 528. https://doi.org/10.3390/s19030528
28. Adesina, T., & Osasona, O. (2019). A novel cognitive IoT gateway framework: Towards a holistic approach to IoT interoperability. *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)* (pp. 1–6). IEEE.
29. Kramer, D., & Haehner, J. (2019). A self-aware systems approach for interoperability in IoT ecosystems. *ARCS Workshop 2019; 32nd International Conference on Architecture of Computing Systems*. VDE.
30. Kotstein, S., & Decker, C. (2019). *An approach for measuring IoT interoperability using causal modeling*.
31. Li, X., You, S., & Chen, W. (2019). Enabling interoperability of heterogeneous identifiers of IoT via semantic code. *2019 IEEE International Conference on Smart Internet of Things (SmartIOT)* (pp. 1–6). IEEE.
32. Bouloukakis, G., Georgantas, N., Kattepur, A., & Issarny, V. (2019). Automated synthesis of mediators for middleware-layer protocol interoperability in the IoT. *Future Generation Computer Systems, 101*, 1271–1294. https://doi.org/10.1016/j.future.2019.07.003
33. Quevedo, J., Corujo, D., & Aguiar, R. (2014). A case for ICN usage in IoT environments. *2014 IEEE Global Communications Conference (GLOBECOM)* (pp. 2770–2775). IEEE.
34. Chen, J., Arumaithurai, M., Fu, X., Ramakrishnan, K. K., & Westphal, C. (2016). Exploiting ICN for realizing service-oriented communication in IoT. *IEEE Communications Magazine, 54*(12), 24–30.

35. Pahl, M.-O., & Liebald, S. (2019). Information-centric IoT middleware overlay: VSL. *2019 International Conference on Networked Systems (NetSys)* (pp. 1–6). IEEE.
36. Dong, L., Ravindran, R., & Wang, G. (2016). ICN based distributed IoT resource discovery and routing. *2016 23rd International Conference on Telecommunications (ICT)* (pp. 1–7). IEEE.
37. Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks, 54*(15), 2787–2805.
38. Amendola, S., Lodato, R., Manzari, S., Occhiuzzi, C., & Marrocco, G. (2014). RFID technology for IoT-based personal healthcare in smart spaces. *IEEE Internet of Things Journal, 1*(2), 144–152.
39. Darianian, M., & Michael, M. P. (2008). Smart home mobile RFID-based Internet-of-Things systems and services. *2008 International Conference on Advanced Computer Theory and Engineering* (pp. 1–4). IEEE.
40. Zhang, M., Yu, T., & Zhai, G. F. (2011). Smart transport system based on "The Internet of Things." *Applied Mechanics and Materials, 48*, 1073–1076.
41. Smith, K., Lyles, M. A., & Scharlach, A. E. (2015). The Internet of Things: The personal and social domain. *Portuguese Journal of Management Studies, 20*(1), 43–50.
42. C-DAX Consortium. (2014). *Cyber-secure data and control cloud for power grids*.
43. Chai, W. K., Katsaros, K. V., Strobbe, M., Romano, P., Ge, C., Develder, C., Pavlou, G., & Wang, N. (2015). Enabling smart grid applications with ICN. *Proceedings of the 2nd ACM Conference on Information-Centric Networking* (pp. 1–10). ACM.
44. Yu, K., Yang, H., Tan, X., Lin, H., Zhou, X., & Shimamoto, S. (2016). Cost-efficient residential energy management scheme for information-centric networking based home network in smart grid. *International Journal of Computer Networks & Communications (IJCNC), 8*(2).
45. Amadeo, M., Campolo, C., Molinaro, A., & Ruggeri, G. (2015). Information centric networking in IoT scenarios: The case of a smart home. *2015 IEEE International Conference on Communications (ICC)* (pp. 1–6). IEEE.
46. Kumar, S. P., Selvi, M., Kannan, A., & Sundarakantham, K. (2017). Smart health monitoring system of patient through IoT. *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)* (pp. 1–5). IEEE.
47. Saxena, D., Raychoudhury, V., & SriMahathi, N. (2015). SmartHealth-NDNoT: Named Data Network of Things for healthcare services. *MobileHealth@ MobiHoc* (pp. 1–6). ACM.