Indian Journal of Science and Technology, *Vol 9(11), DOI: 10.17485/ijst/2016/v9i11/89289, March 2016*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Survey of Migration, Integration and Interconnection Techniques of Data Centric Networks to Internet- Towards Internet of Things (IoT)

Kayalvizhi Jayavel[1]* and V. Nagarajan[2]

[1]Department of Information Technology, SRM University, Kattankulathur - 603203 Tamil Nadu, India; kayalvizhi.j@ktr.srmuniv.ac.in
[2]Department of Computer Science, SRM University, Kattankulathur – 603203, Tamil Nadu, India; nagarajan.v@ktr.srmuniv.ac.in

Abstract

Background/Objectives: Internet of Things aims at creating Web of Things connecting anything, anytime and anywhere also embracing Cyber-physical systems. **Methods/Statistical Analysis**: The underlying data source being sensors or interconnection of them, predominantly communicating wirelessly (WSN), our paper attempts to survey and analyze all the interconnection models that provide information to the users exploiting or extracting information at their own capacities. We have grounded our survey based on the role of gateway and nodes, hops, connection points, robustness, suitability, resilience, scalability, topology and their adaptability towards IoT. **Findings:** As of now surveys have been made in silos like various interconnection techniques or migration techniques for Wireless Sensor Networks to the best of our knowledge not much have been proposed about the feasible interconnection model towards Internet of Things. Our paper attempts to fill this gap and we have also studied the possible adaptation and integration of techniques like Software Defined Networks and virtualization towards Internet of Things. Software Defined Networks can provide us the much needed control for the Internet of Things and virtualization can provide us with re-usability. We have also highlighted how we can visualize a sensor node as a service or as a database. As of now very less work has been carried out about integration of these towards Web of Things. **Applications/Improvements:** We are also developing an architecture incorporating these layers namely the SDN and the virtualization and we have planned to test it using real time deployment in future.

Keywords: Data Centric Networks, Integration of WSN to IoT, Internet of Things (IoT), Software Defined Network (SDN), Survey of Interconnection Techniques, Virtualization

1. Introduction

Internet of Things (IoT) is connecting every existing thing or device or thing to the Internet. Many researchers are working in this direction and still lots of issues remain unattended, a 2014 paper confirms[1]. IoT is a distributed dynamic heterogeneous infrastructure and it becomes vital for it to combine different protocols, technologies and access models to provide services in the needed way. As the area is very diverse, we have opted to limit our work with integration of Wireless Sensor Networks to the internet as a step towards achieving IoT. The interconnection of WSN and IoT has numerous application areas[2,3]. HP labs are working on worldwide sensor networks in order to create central nervous system for the Earth[4].

Many researchers have worked for so long about various ways of achieving the needed interconnectivity. There exists obvious incompatibilities in integration but numerous solutions do exist which is substantiated through this survey. But we feel all these solutions could be grouped

**Author for correspondence*

within two broad categories namely Stack based and Topology based. Stack based model can be categorized in to 3 subdivisions Front-end Gateway, Translation Gateway, Void Gateway. Topology based model has 2 sub divisions Multiple Gateway and Access Point approach. All these interconnection methods are described with clarity with proper emphasis on merits and the drawbacks that lead to other approaches. This paper also attempts to provide further possible ways existing for migrating non-IP based networks in to the omnipotent IP based backbone which are clearly the extensions or up gradations or modifications of the above stated approaches which currently exist.

2. Need for Integration

2.1 Issues existing in integration of WSN to IoT

Wireless Sensor Network[5–8] being Data centric[9] as already mentioned carries along with it bundle of issues to work up on. WSN's being Data centric the protocols and standards are very much different when compared to traditional application specific IP based systems[10]. Data centric addressing is more apt for Wireless Sensor Networks as the nodes are identified based on the data generated or based on a geographical location but never based on its identity i.e. address. The data demanded by the user/client application may not be possible of generation from one particular node; the need may be to integrate/aggregate the data collected from various nodes before sent back to the user. Many data aggregation methods via gateway exist. Most popular among those are Directed Diffusion[11] and SPIN[12]. The benefits they offer are reduction in traffic due to minimum communication, redundancy and thereby reducing the energy consumptions which might have occurred without aggregation. These merits do not come for free. There need to be some cost paid to achieve as to enable data aggregation, the application specific code i.e. data cache and integrative signal processing has to happen at nodes very near to the data collection venue. Thereby these nodes compared to the nodes away suffer faster energy drain.

3. Comparison of existing Interconnection Techniques

This section provides the various interconnection techniques that exist till now to integrate Data centric networks towards internet. The methods are covered in the order of their merits, the minimal to the maximum. A comparison Table 1 is provided at the end of this section for consolidation.

3.1 Stack Based

3.1.1 Front-end Gateway

The Frontend Gateway approach a stack based approach is the oldest of its kind in interconnection of WSN to internet. Frontend Gateway-indirect called so for the reason was never the user will be able to communicate with the WSN node directly. The WSN nodes submit their data to a sink node which may be a PDA or PC. The client only connects to this sink node for details. The drawbacks are:

- Users cannot talk to WSN nodes i.e. no connection exists between WSN and internet directly.
- Communication is non-interactive on the sensor side and unidirectional in either way say from user to WSN or vice-versa.
- Nodes at closer proximity drain energy faster.
- Complete disconnect on the single sink node failure

In order to improve the above pitfalls a new interconnection technique, Translation Gateway approach was proposed.

3.1.2 Translation Gateway

In this method WSN hands over the data to a more powerful node, the Gateway. This method is also named as Translation Gateway-indirect since this approach too fails to provide direct connection between WSN and internet. The Gateway can be a personal computer and it takes care of relevant conversions with the help of appropriate protocols that it possesses. Users get their details through internet connecting to this Gateway and the Gateway is capable of talking to the WSN and thereby gets data dynamically. There is another approach which uses IOT Gateway system based on Zigbee and GPRS protocols[13] as against plain internet. Both of them provide bidirectional interaction. Still few areas of improvement exist as follows:

- Users can interact with WSN as against the previous approach but still indirectly.
- Nodes at closer proximity drain energy faster.

- Complete disconnect on the single sink node failure
- The next approach Void Gateway was proposed to mitigate the above issues.

3.1.3 Void Gateway

As we all know the best way to get connected to internet is through TCP/IP stack[14]. Hence the essence of this approach is to port a TCP/IP stack in to every sensor node. We do know that these sensor nodes are extremely resource constrained say battery operated and inaccessible in many areas based on their application like forest fire, volcanic eruptions and tsunami alerts etc. Thus a lot of critical care needs to be taken to decide on the ingredients that go inside every sensor node starting from the application codes to translation software and protocols. Though there is huge improvement in hardware resources due to MEMS technology, yet WSN still has its own unavoidable limitations due to its application specific nature. Hence this approach takes the burden of porting a reduced version of TCP/IP stack in every node[15]. Many reduced version of TCP/IP stack exists say µIp[16], 6LoWPAN[17] etc. Due to this reason this method is also named as TCP/IP-Direct. Some merits of this approach are:

- No Gateway exists to interconnect.
- Direct connection exist
- Extremely interactive and dynamic.

Though this allows every node to directly interact with the internet, it achieves it at a cost. The drawbacks are:

- Legacy systems exist which are non-IP and it is near to impossible to port TCP/IP stacks in them.

As this approach demands all nodes to be addressable, it brings in extra complexity of address administration say need for DHCP[18] (Dynamic Host Configuration Protocol). In case mobile nodes, multi-homing and mobile IP becomes unavoidable.

Above all, we really need to pack of bytes of data from WSN in to a 40 byte header in case of Ipv6 just to achieve interconnection. Though there are header compression techniques, do we really need to pay this far an interconnection? May be No.

Thus researchers thought of making hybrid solutions thinking it could arrive at an agreeable balanced solution. Hence they came up with the next set of interconnection models the Topology based.

3.2 Topology based

The Topology based interconnection derives its name as the emphasis is on arrangement of Gateway nodes and about the accessing capabilities. This proposal was made to mitigate and improve the already existing Sink based approach. This approach is not an alternative to the previous methodology. But this with its modifications in the structure and incorporating redundancy attempts to drift the interconnection reliability to its next level[19]. Later Gateways were made capable of aggregating and filtering the data as well[20]. There exist two sub-divisions namely Multiple Gateway model and Access point model.

3.2.1 Multiple Gateway

Multiple Gateway approach is also named as Hybrid approach. The multiple Gateway model as the name signifies is a refinement of the Translate Gateway-indirect approach which in originality suffers single point of failure. So this approach provides a simple solution of providing Multiple Gateways. In other words it combines redundancy and network intelligence to improve the reliability. Redundancy is achieved through Multiple Gateways and network intelligence, because those nodes or Gateways or Base stations have the capability to connect to the internet. It is a good sign that some of the intelligence have been migrated in to WSN which earlier was only under the control of internet based networks. Every little improvement made brings with it some constraint/tradeoff/complexity as a by-product which is unavoidable. This method too is no exception. Some of the drawbacks in this approach are: Which Gateway the sensor nodes of the WSN have to report to? How the user will know which Gateway has information of what? There is a need for a mapping table been created and made available to the user prior, so he could contact the right Gateway. This increases the complexity.

3.2.2 Access Point based

Access point model also named as Backbone approach has come out with a very interesting proposal as it touches the core requirement of any internet based system i.e. ability to connect to internet with just one hop. This was not addressed in any of the previous methods which are all by default uses multihop to reach the sink (user node/

Personal computer) from the source (sensor node/nodes) discussed above. This one hop is made possible by creating an unbalanced tree structure with multiple roots where leave nodes are all normal sensor nodes meaning no internet capability and all other parts of the tree are internet enabled. This approach is refinement of TCP/IP-Direct proposal, the latter has its entire node TCP/IP enabled. This approach finds its way in cases where you have to scale an existing legacy networks which are non-IP based in to the internet backbone based networks. This approach too provides a compromise but fails to provide a flawless solution.

All these above approaches have concluded the need for a completely new paradigm shift in the interconnection approach. Many researchers have started working in this direction and among them we found two approaches highly progressive towards the ultimate goal of data centered network migration to IoT. The first one considers every sensor node as a database. And, the next approach attempts to consider every senor node data as a service which shifts sensor data towards web services. The next two sections attempts to debate on both of these approaches whereby concluding with valid substantiations that the web services approaches excels more than the database approach.

3.3 WSN as a Database

Sensor nodes are represented as Databases. The information can be retrieved through SQL queries[21]. This approach has two types of implementation namely centralized and distributed. In centralized approach all the sensor nodes send their data to a central server and the user query the central server to get the needed details. Drawbacks include creation of traffic hot spots near the server, lack of in-network aggregation increases communication load, more power consumption, Failure of server leads to complete system shutdown. The next approach allows data to be stored in the network itself. This allows queries to be injected anywhere in the network. Advantages are only relevant data are extracted from the network based on requirement of the user, allows data aggregation before data being sent to the external query. But still this fails to offer interoperability between networks due to its constrained with respect to SQL queries. Having compromised with these entire still there is issue with respect to interoperability due to various sensor database designs say TinyDB, Cougar etc. This model too demands a strong coupling between the database model and the application querying the network which hinders the application independent querying through arbitrarily selected sinks. Thus leaving a space open for a even more better model.

3.4 WSN as a Web Service

The problems stated above can be very well eliminated with a standard model like Web service. The Web services approach[22] provides the much needed interoperability of various Wireless Sensor Networks. This is achieved through the use of Service Oriented Architecture (SOA) through WSDL (Web Services Description Language) and SOAP (Service Oriented Access Protocol). Both of them are accepted internet standards for describing, communicating data and interest in Wireless Sensor Networks too.

Features like modular, independent and self-describing makes Web services an attractive approach for Wireless Sensor Networks. The most added advantage is they can be accessible through ubiquitous internet protocols like HTTP and universal data formats like XML. Service Oriented Architecture defines 3 roles namely service provider, service requester and service registry[23]. Service provider is responsible for creating service descriptions and publishing that service descriptions to one or more service registers and receiving web service invocation messages from one or more service requesters. Besides the roles there are three important operations as part of Service Oriented Architecture. They are Publish, Find and Bind.

- Publish: Is an act of service registration or service advertisement.
- Find: Allows the service requester to state search criteria like type of service
- Bind: helps to establish relationship between service requester and service provider.

Each of the above operation is achieved with the help of protocol stacks, publish and discovery stack, description stack and wire stack[23] or exchange format stack respectively. The whole idea of transforming the wireless sink nodes are web service provider was to eliminate the traditional process. Figure 1 illustrates WSN as service and data accessed through Gateway/Proxy. The authors have made an assumption that all sensor nodes have processing and storage capacities to store and execute

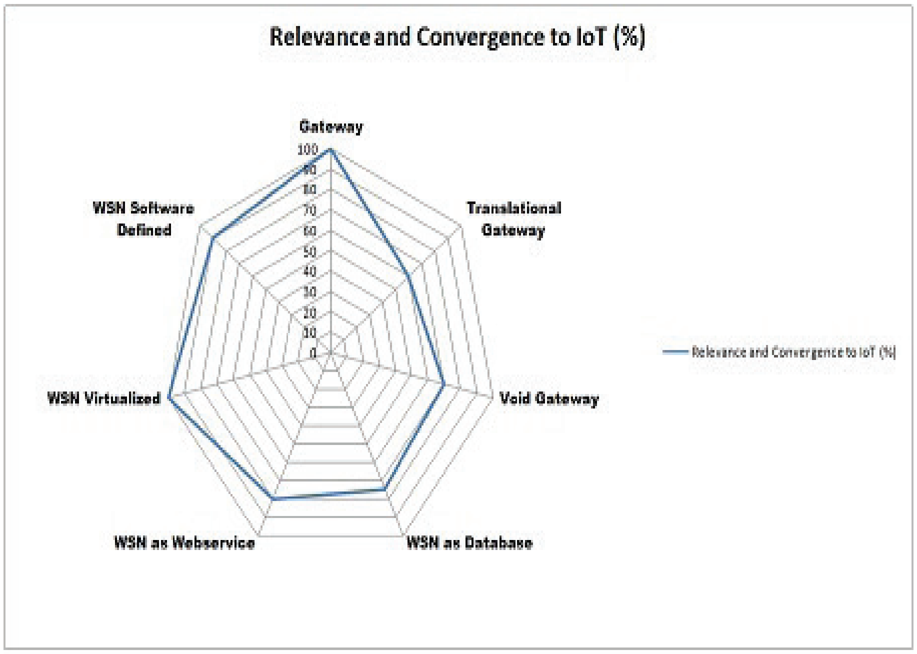

Figure 1. WSN as service and data accessed through Gateway/Proxy.

aggregation filters. Recently researchers have used this model to measure environmental parameters like temperature, pressure etc[24].

The traditional process was designed for specific application which in turn is strongly binded to specific data communication protocols. Though beautifully architects WSN's towards flexible description and communication of data and interests, but at an extra cost or burden. As this demands use of service description languages like WSDL, the associated protocol SOAP even though they are fully qualified internet standards. And now the migration toward cloud has become a requirement which creates issues at Service Level Agreement as there exists no standard language to describe the cloud services. Yet another issue that needs to be addressed is reusability of sensor nodes. There exist numerous sensor nodes dedicated for certain applications and remain idle most of the time. The solution to this problem could be virtualization of Wireless Sensor Networks.

3.5 Comparison of Different Integration Techniques

The following are the meanings for the symbols used in the Table 1 which gives specific details of the different types of integration that are relevant to this paper.

3.5.1 #Sink Based

In this approach all the nodes submit their data to the Gateway. Users query the Gateway. In case of unavailability of data the Gateway does not interact dynamically to retrieve the data. Not interactive.

3.5.2 &Translation Model

This is a variant stack based model. Unlike sink based model this is capable of providing response based on user query dynamically. Indirect Interactive model as it happens through Gateway.

*3.5.3 *Void Gateway*

Sensor nodes by themselves have small foot print TCP/IP stack in built. Need to pack just few bytes of data in a 40 byte header which adds up extra overhead.

4. Virtualization and SDN towards WSN

Most of the Wireless Sensor Networks are tailor-made solutions deployed on field with no possibility for other applications to re-use the deployed WSN. The nature of WSN is that it juggles between active and sleep states.

Table 1. Different integration techniques of Data centric networks towards IoT

Type of Integration / Characteristics	Independent	Hybrid	Access Point	Void Gateway
Broad category	Stack Based	Topology Based	Topology Based	Stack Based
Gateway	Single Gateway	Multiple Gateway	Multiple Gateway	No Gateway
Role of Gateway	Process, Translate, Forward	Translate, Forward	Translate, Forward	Nil
Role of Nodes	Sense and Send	Sense, Process, Send	Sense, Process, Send	Sense, Process, Translate, Forward
Number of Hops	Multiple	Multiple	Single	Single
Connection Point	All nodes are assumed at equal capacity	Few nodes are considered more capable	All of them are considered equally powerful	All of them are considered equally powerful
Robustness	Not Robust	Robust comparatively	More Robust comparatively	Robustness at its best
Suitability	Suitable for Static Networks only	Suitable for Static Networks only	Suitable for Static Networks only	Suitable for Dynamic networks
Resilience	Poor. Gateway Failure Whole Network down	Good	Better	Best
Scalability	Possible. But demands time consuming reprogramming of Gateway	Possible. But demands time consuming reprogramming of Gateway	Possible. But demands time consuming reprogramming of Gateway	Possible at ease
Topology	Star	Mesh, Multihop	Mesh, One-hop	Mesh, One-hop
Adaptability towards IoT	Not suitable	Yes but with a huge cost	Yes but with a huge cost	Yes but with overhead *
Popularly known as	Front-end Gateway, Sink based model#	Multiple Gateway	One-hop/Backbone approach	TCP/IP Direct
Topology Dependent	No. Stack based approach	Yes, depends on Gateways and its location	Yes, depends on Gateways and its location	No
Variants	Translation Model &, Void Gateway*	-	-	-

Though the existing interconnection techniques come closer to our requirement to integrate towards IoT, they suffer very badly when comes to re-usability and dynamic assignment. And on an average our WSN resources remain unexploited, to the extent it could have been. Virtualization would come for our rescue[25]. Virtualization is a concept where the Operating systems can be separated from the underlying hardware. Cloud an enhanced virtualization version of web services will separate the application from the underlying hardware[26,27]. And to exploit even further, the control plane and data plane can be segregated which is the basis for Software Defined Network. All the concepts of virtualization, cloud and SDN[28] where considered more apt for a wired scenario, not much have been explored towards the WSN domain. The first step in this direction is to separate the sensor infrastructure from the application or service to be deployed. Some of the researches have very recently started working in this direction[29].

Figure 2 indicates the relevance and convergence of the techniques studied so far with respect to IoT.

5. Conclusion and Future Work

Data centric networks like WSN, which are considered to be the most application specific networks, were developed

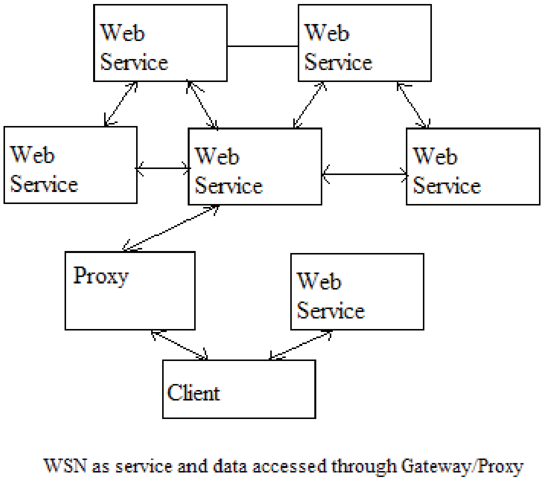

Figure 2. Relevance and convergence of the techniques with respect to IoT.

with the intention that they can live alone. The need of the hour is to integrate these networks to the internet for the purpose of achieving the ultimate goal, IoT.

Traditional ways like Stack based and Topology based interconnections exist to interconnect these networks. There are many flaws that exist in these methodologies, which bring in the need for a completely new paradigm shift in the interconnection approach. All the characteristics of the traditional methods are summarized in Table 1.WSN as a web service and WSN as a database provide a better solution for interconnection. However, WSN as a database has an issue when it comes to interoperability, which is solved by WSN as a web service. The concept of virtualization comes into place when there is an issue with respect to re-usability and dynamicity with WSN as a web service.

Virtualization, cloud and SDN[30] provide the best way to interconnect the WSN[31]. But, all the concepts of virtualization, cloud and SDN were considered more apt for a wired scenario, not much have been explored towards the WSN domain. The issues faced by SDN, virtualization and cloud as individual concepts should be taken into consideration. Researchers have to come up with an ultimate solution as there are issues in each and every methodology. Power drain and cost are few of the factors to be considered while addressing this problem. In future, the data centric networks, after reintegration to the internet, will create a system where any data can be accessed from anywhere at any time creating the Internet of Things. Researchers have come to a conclusion that virtualization will be the future for Internet of Things. Many Data centric networks like WSN have started migrating towards virtualization. Apart from virtualization which makes reusability a possibility, Software Defined Networks (SDN) if incorporated will enhance the performance of existing WSN's.

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