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Web3.0: Innovative Applications of SmartObjects in the 'Internet of Things' Networking Architecture

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ABSTRACT

Web 3.0 is considered as the upcomingrevolutionary step in the history of the World Wide Web.Field specialists expect Web 3.0 to be innovations over what became known as 'The Read/Write Web - Web 2.0', providing even more interaction and collaboration between users. Suchstandard foresees the next semantic generation of the web, where numerous physical objects, digital or even non-digital, would constitute a major part of theInternet. The ability to connect objects to the Internet on a global scaleis expected to leverage them into 'smart objects' that are capable of intelligent interaction with their surroundings. The main purpose of this paper is to investigate the required developmentsof this technology, providing a realistic technical overview of its functionality in terms of networking and its relevant architecture. Data sharing and remote control are two main concepts that will also be covered, starting with the general functionality and ending with the communication protocols between digital devices. Then, a critical analysis of the functionality, scalability and adaptability of such technology is presented, before drawing some conclusions on the social and ethical implications that accompany the human role in Web 3.0.

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INTRODUCTION

Web 3.0 is a revolutionary step in the development of the web, where many everyday objects are Internet connected and remotely controlled under the umbrella of the protocols and standards of such web technology. Also known as'The Internet of Things' (IoT), thisupcoming phase of web technologyuses the Internet as a mediumfor the interactionbetween and with smart objects, and consequently,shapes our involvementswith the smart spaces around us. Such standard of communicationpredicts the conjunction of severalfunctionalities and the interconnection of everyday-objects maintained through the Internet and its current architecture.

Looking through the present landscape, the adoptionpossibility of the Web 3.0 technology through the current adaptation of advanced wireless technologies, such asRadio Frequency Identification (RFID), enabling the connection of a vast variety of physical objects to the Internet, sharing their data collected from the environment through Wireless Sensor Networks (WSN) (Hammoudeh, M., 2015& Newman, R. 2015b) Artificial Intelligence (AI) and pervasive computing. Such smart settings will be sensitive to the activities of users, responding and adapting to unique individual needs (Aarts E and Wichart R, 2009).Thus, the creation of such 'smart objects' follows the intricate implementation of the semantic web expertise, where 'metadata' underlies the complications of such data structures, describing specific instances of data application or data content, and allowing the effective communication with other devices or services to meet a common goal. The seemingly digital world created by the applications of such web technologiesenvisionsthe goals of IoT, focused in the formation of a digital world were humans are seamlessly integrated with physical objects forming a digitally enhanced smart environment.Hypothesizing such a paradigm combines the understanding of our daily needs with the latest advancements in everyday services, such as education, enterprise or even healthcare, to further enhance our interactions with the information technology in society.

Nevertheless, such an archetype will not implement easily as long as the current supporting architecture, the Internet, is an arrangement of heterogeneous web-based networking services implied through interactive devices. Moreover, the achievement of IoT runs in parallel with the success of the effective communication between the different components of such technology, whether machine-

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to-machine orhuman-to-machine communication, since operative communication is a vital aspect for the reliable and integral functionality of smart objects. From such argumentative principles, this paper draws comparative and contrasting challenges and solutions of smart objects facilitation, emphasizing the layering and organization of networking topologies. The current research in this field will be surveyed in order to examine the communication protocols and standards that support the upcoming revolution in web data transfer. We will also investigate two outstanding wireless communication protocols, evaluating the possible benefits and drawbacks towards smart object functionality and design. An examination of the future possibilities for the implementation of Web 3.0 and smart objects will conclude the following arguments discussed throughout regarding the findings about IoT.

2. FundamentalConcepts:

It seems a necessity to provide and elaborate the few concepts related to the technology of Web 3.0 as well as IoT. To many, such technologies are the normal consequences the revolutionary web technology is yielding over the course of time. The eventual yieldis the long dreamt of – 'Smart Objects', but no matter where the technological wave is drifting, the networking architecture of IoT is a predictable drift that we can investigate to develop such a global technological uprising.

2.1 The Internet in Progression:

The Internet, operating on the TCP/IP protocol, is the largest physical network across the globe, providing an architecture that allows an infinite number of devices to connect, communicate, access and even manipulate information on a global scale. As of July 2011, the estimated number of machines connected to the Internet was around 850 million, not including intermittently connected devices such as smartphones or laptops (Nie, N. H., &Erbring, L., 2000).

Increased development and advancements in the field of WSN accompanied with the recent cost reduction of embedded devices made it more feasible to use the pre-existing networking architecture of the Internet to interconnect objects of everyday use (Hammoudeh, M., & Newman, R. 2015b). Eventually, the normal course of growth in web technology took the next level of advancement; the Internet of Things (IoT) – A term first used in 2009 by Kevin Ashton of MIT. Figure 1 illustrates the course of development undertaken by the Internet through its history as described by Stefan Ferber (2011).

All significant steps in the development and evolution of the Internet can be highlighted in the following phases:

1. **Web 0:** This phase refers to the simple connection of two separate machines forming a network.
2. **Web 1.0:** This phase refers to the first phase of the World Wide Web, where the vast majority of users acting as consumers of the content (Cormode, G. and Krishnamurthy, B., 2008). Also known as the 'Read-only web'.
3. **Web 2.0:** This refers to the ability of users to view as well as contribute contents to the webpages they access within their browsers. Also known as 'Read/write web', the connection of smartphones to the World Wide Web was generally witnessed in this phase of Internet evolution, as well as the emersion of people's identity on the found social networks.
4. **Web 3.0:** Also known as "The Internet of Things", the anticipated phase of web development interconnects physical objects of everyday life to the Internet, allowing for the more complex interaction between people and machines in a real-life balanced context.
5. **Web 4.0:**This phase is known as the ultra-intelligent electronic agent. It is still long way before it is implemented as the third age of the web is only just getting started. Web 4.0 is an always-on world, where people can self-upgrade through technology extensions.

We can generally state that the Internet of Things (IoT) is in fact emerging with the world witnessing its early stages of development, forming a primary vision were people are demanding the integration of objects to meet their ongoing needs. Nevertheless, as the technology of the web advances, the eventual vision of IoT incorporates seamlessly and pervasively by its mere presence in the global society, and such vision involves three dimensions according to outlined below:

1. Vision of Semantics:

'Semantics' refers to the addition of metadata to add meaning to ordinary data collected through sensors. This envisions the meaningful processing of the vast amount of data collected through sensors.

2. Vision of Things:

The prevalenttracking and interaction with everyday objects using the ordinary sensors along with developed wireless communication technologies, such as Radio Frequency Identification (RFID).

3. Vision of the Internet:

The vision of a global network connecting objects on the current TCP/IP protocol, providing unique network addresses and creating the required smart objects.

The above-described broad-spectrum vision of IoT can be easily seen as overlapping, such that all technical anticipations of the technology overlap to be interdependent on each other to form the well-developed model of IoT.

2.2 'Smart' Objects Ideology:

With the pioneering wireless sensor technology, variousphysical objects can be tagged with information via RFID, with such information being accessed through browsing the networking address associated with it (Kosmatos*et al*, 2011). As a result, objects tagged with RFID tags can be easily identified using RFID readers that can query the tag and retrieve its information, thus giving the object a digital identity to become part of any sort of controlled network.

Hence, the term "smart objects" refers to devices that can be considered as 'small computers'embeddable with protocols dictating communication, actuators, and sensors, executing object-to-object communication, verifying their current state in addition to providing unique identification.Most importantly, the need of smart objects to support ad-hoc networking, and perform object-centred complex decision-making offers the unique functionality, reliability and complexity of such devices (Lopez T *et al*, 2012). Such combined functionality allows smart objects to extensively gather information from the surrounding environment contextually and specifically via sensors to transfer the collected data for further processing using the accessible network, often via wireless connections. Updatescan be pushed to smart devices in use to ensure their reliability and integrity, usually using a web service or even a middleware source. For instance, the package delivery system in an enterprise records GPS locations for logistic purposes, transferring such data to an IoT specified server to become a contributor to the network. Non-electronic objects, such as food items or clothing, can represent the unlimited idea of object in the IoT technology, by using the same principles of tagging and identification.

The need for the adoption of a wireless communication standard arises from the fact that most smart objects are mobile and cannot be connected directly through a wired topology to a network. Remote power sources, such as lithium batteries, are devised for use in such situations to power the three main components proposed for any smart object: A memory chip, a CPU, and a wireless networking utility.

When considering the most suitable network platform to support smart objects, the TCP/IP protocol of the Internet seems definitely suitable, possessing a legacy of communication for interoperable global networking across the different services that run on the Internet, such as FTP, HTTP or IRC. Considering the IP protocol, it is technically stable, well developed, and integrates well with various services,for instance the email or the World Wide Web (Dunkels A, 2010). Figure3 illustrates the logical implementation of the RFID system that transmits data wirelessly to a special receiver, which in turn will analyse the data and forward it through an IP-based network to a main central server for further processing.

2.3 IoT: The Technical Architecture:

Technical architecture of the applied Web 3.0 'Internet of Things' refers to three main tiers according to Szabo*et al* (2014), exclusively including the devices, control, and the DC/Cloud tier.

The devices tier in fact refers to the various devices in the Wireless Sensor Network (WSN), loaded with sensors and located on the network edge. These devices collect contextual data from their environment and communicate their state with the appropriate serving device on the network. The information generated from the sensors varies according to specific purposes.

As can be seen from figure 4, the middle control tier integrates various LANs on top of the original WSN intricate topology, with the combination utilized for the transport of captured information via the sensors to the chosen destination. The uppermost DC/Cloud layer is comprised of the necessary processing, interpretation, presentation and management of the delivered information of the sensor.

3. The Interconnection of Smart Objects:

As any technological device designed and required to share data and give a specified-scenario response to particular contextual stimuli, smart objects demand effective means of communication to ensure reliable and integral processing of data. Following is an exploration of the most popular communication protocols especially designed for the low-power consumption and wireless communication of smart devices, raising a subsequent list of challenges that need to be overcome for the effective functionality of smart devices.

3.1 Protocols of Low-Power Wireless Communication:

Various existing low-power wireless standards create the base protocol for the low-power communication of smart devices, competing in the wireless communications market, with each having its specific mode of function and connection. Therefore, each network layer protocol competes with others analogous in function in similar market standards, aimed at meeting the demands required in certain situation-based issues.The major competing technologies used in WSN architecture, including their technical standards and the type of network they create, are summarized in table 1 for comparative purposes.

It can be clearly established from the above data that the group of protocols that manage such specialized standards are not all managed by the same organization or group. A possible explanation for this is the fact that each group exhibits special interest regarding certain technologies within various competitive markets. For instance, Near Field Communication (NFC) mainly functions with placing your mobile within close proximity of a receiver (Point-to-Point requiring aiming the device) to quickly transmit data in cases of digital identification or payment – a phenomenon known as 'bumping', while Bluetooth wirelessly connects a mobile phone, for example, to a car radio, promoting what has become known as "cable replacement".

Technical comparisons of several aspects of such protocols, including important features such as power consumption, were carried out by Mohammed *et al* and Tabish R *et al*. Such deductive findings can be used to further assess the applicability of the compared technologies in the use for smart object development.

3.2 Anticipated Challenges:

Portable computing is growing drastically, and computing power itself is indeed a reflection of Moore's Law and its observation (Moore G.,1965). On the other hand, the advance in energy storage and battery technology, unfortunately, is not coping with the demands of the other components of this technology (Gast M., 2014). The implications of such technical incompetence in case of smart object design would directly concern power consumption and overhead limitations on WSN technologies, along with the protocols supporting data transfer. The challenges faced are similar to those faces in other Wireless Personal Area Networks (WPAN); however,due to the integrated complexity of smart objects, power consumption, mobility and interpretability are aspects of primary focus. Below are the different challenges faced in smart object design:

1. Network Requirements:
- Low power consumption
- Multiple node communication
- Network density handling
- Suitable data rates (Bandwidth)
- Data interpretability (type and integrity)

2. Objective Challenges:
- Reliability
- Feasibility/cost effectiveness
- Feasibility/running platform on IPv6
- Size and complexity

3. Security:
- Data encryption
- Authenticity

4. Accessibility:
- Ease of use
- Ad-hoc networks and infrastructure
- Data transfer between the associated Access Points (AP)

5. Intervention:
- Quality of service
- Wireless range
- Latency

Further exploring the security, mobility, and objective challenges is not in the scope of this paper. Instead, the focus of this research is primarily on the research conducted at the level of the network layers protocols that support data transfer in WPAN within the networking areas.

3.3 Wireless Range and Power Consumption:

Range, being generally defined as the area of functionality for a wireless network determined by the sensitivity of the receiver and the power of the transmitter, is of critical importance for smart objects determining the size of the network architecture and accessibility. Table 2 is an outline of the power consumption and maximum range of each protocol made for comparative purposes between the different standards.

Being dependent on the environment and the protocol chosen for network functionality, nodes for the WPAN/WLAN networking protocols will have to be located within a reliable adequate range to function successfully. Doubtlessly, this constrains the total network size, and with the intention of expanding the range, several nodes need to be used, eventually increasing the node density of the network. This expansion seems cost-efficient for spreading the network coverage, yet some smart objects are portable and movable, creating multi-hop transmissions in transitional nodes of the local network, affecting throughput and latency.

When discussing power consumption, it is obviously known that technologies such as ZigBee and NFC considerably require more power than others. ZigBee competes with Bluetooth, requiring more functions that are complex; consuming more power, while NFC is not commonly used, and hence would not impair its use since it would not be a major contributor to draining a device battery.

3.4 Latency and Application Throughput:

The maximum rate at which each possible WSN standard can transmit payloads of data that can be considered useful is shown in table 3. Such standards are unlikely to be transmitting high levels of data very frequently since they are designed with "Sleep-awake" modes for low level monitoring. It can be deduced from the investigated results that throughput rates are similar to each other except the ANT standard that can manage 20 kps only using a different method called "Burst data rate". Hence, the performance of the NFC standard is the best in spite of the fact that it requires pointing the device as it is a "Point-to-point" network.

When considering latency, it is seen that the ANT standard has the lowest level without a doubt, although it calls for the receiving device to 'listen' uninterruptedly, consuming more power as a drawback. ZigBee and IrDA both have an average performance depending on manufacturer standards and whether or not the device is in a 'sleeping' state.

The range for the IEEE 802.15.4 Based Motes is extremely wide, giving this standard flexibility in performance from the relatively good to the poor inadequate performance, depending on situation-specific configuration of the components.Having explored a variety of the most popular low-power wireless protocols that can accommodate Web 3.0 anticipated networking architecture, it is crucial to discuss two contending protocols in more detail, the 6LoWPAN and ZigBee, due to their major contribution to such development.These two protocols are based on the same standard of IEEE 802.15.4, enabling both of them to be used in solving the issue of low-power WSN within smart objects.

4. ZIGBEE and6LoWPAN PROTOCOLS:

To begin with, the IEEE 802.15.4 standards are groups of protocols constructed on the basisof the physical and data-link (MAC) layers. Being especially designed for overcoming the technically limiting restraints of low-power by providing low rate of wireless communication for data, such standards build the basis for low-rate wireless personal area networks (LR-WPAN). This is made possible through the implementation of the following qualities: General low power consumption, low transmission power, small Maximum Transmission Unit (MTU), and low cost (Ott A.,2012).

ZigBee and 6LoWPAN are considered the most prominent wireless communication protocols when it comes to providing low-power communication for small embedded electronic items. Both protocols are, by definition, network layer protocols based on the IEEE 802.15.4 standards, using its networking properties.Moreover, the two protocols are organized to establish a communication medium within low-power WPAN, specialized in the contextual monitoring of the environment and other corresponding devices. An application derived from such an organized technical scenario is the measurement of power consumption of the host device. Figures 5 and 6 illustrate the communication stack of both protocols. It is worth noting that the 6LoWPAN protocol is a simple IP-based stack, and that ZigBee possesses more abstraction layers, including but not limited to an adaptation layer for interpretation.

4.1 Protocols for Data Routing:

The 6LoWPAN protocol can only operate in asynchronous mode, and it is essentially founded on IPv6. Dr H. Babu (2014) discusses how 6LoWPAN contributes to IP routing and mobility management by defining three separate topologies for its nodes: Simple topology connected to one edge router, ad-hoc (structure less), and the extended topology connecting to multiple edge routers. 6LoWPAN continues to use a system called 'neighbour discovery' for registering nodes in routers depending on their type in order to structure the communication mechanisms within the formed network. As stated by Dr H. Babu and Urmila Day, nodes have to meet four different criteria: (1) to support 'sleep mode', (2) provide overhead costs for data packets that are low, (3) provide low overhead costs also on routing, and finally (4) offer minimal memory requirements and computer processing.

6LoWPAN is able to use RPL (pronounced "ripple") networking layer such as IP algorithm to test the low power listening for energy saving, indirectly by adopting a routing topology upon the physical network (Vasseur JP *et al*., 2011), managing handoffs by nearby nodes (Babu H, 2014).Figure 7 demonstrates the order that the routing protocols create, creating the associations of each sub-protocol with the designed four uniquetopologies. Sub-protocols of the base layer offer a varied set of routing algorithms based on the undertaken topology.

The ZigBee protocols majorly support three varieties of topology; peer-to-peer, mesh and star topologies, with all defining the structure of the communication pathway. ZigBee, being similar to 6LoWPAN, also uses a neighbour detection operation thatcontrolsways depending on the used topology.ZigBee then normally implements two sorts of routing protocols: Ad-hoc on demand distance vector (AODV), and the cluster-tree (CT) algorithm. Routes are established on demand once they are needed, and are maintained as long as they are in use, thus contributing to the 'sleeping' mode of the routing protocol.In such routing protocols, the network is said to remain silent until a connection is needed, and at that instance, the intended network node that needs a connection broadcasts a request for connection until the connection is established.

Saraswala P (2013) further explains the functionality of such routing protocols and justifies that AODV actually puts in context three types of messages: routing requests (RREQ), routing errors (RERR), and routing replies (RREP) so as to determine and sustain routing pathways between nodes using UDP packets.The subsequent dynamic routing information is deposited in tables. Figure 8 illustrates the entire pathway taken by data, structuring the dynamic path of routing messages between nodes. Culer (2007) suggested that the tree routing procedureallowsthe creation of multihop-transmission in a cluster –tree hierarchy.

Cluster-tree (CT) exhibits unique properties when compared to the 6LoWPAN hierarchy and AODV. This is mainly due to the initial selection of a parent node by the CT protocol, then other nodes that subsequently join the network become the 'children' of the parent node (P Saraswala, 2013). The route taken by the nodes creates the layout of the tree, and hence the routing proposed destinations. Figure 9 illustrates the CT structure.

The CT protocol maintains a low-power sleep position for a certain period as it runs a beacon-enabled approach,in that way it allows the nodes to shortly run a low-power status of sleep.

4.2 Interoperability:

In spite of the fact that both 6LoWPAN and ZigBee are created on the basis of the 802.15.4 standard, ZigBee can provide a scheme–based protocol improving the interoperability for networks and their associated sensors, such as CoaP. On the contrary, the 6LoWPAN can make use of the 802.15.4 Media Access Controller (MAC)similar to ZigBee, besides running other physical circuits (PHY) since the 802.15.4 standard is actually classified as both a MAC and a physical layer protocol (OSI layers 1 and 2). The benefits for adopting the 6LoWPAN standard lie in the possibility of operating on a number of physical layer interfaces, therefore allowing unified integration with the whole of the IP-based systems (Toscano and Lo Bello, 2012).

4.3 Security:

Both ZigBee and 6LoWPAN are considered secure since they are essentially based on the AES 128 encryption standard, which has compatibility with IPv6. As a matter of fact, both standards possess multilevel encryption schemes comparative to the level of complexity. Ironically however, it is recommended to implement a moderate-to-low security standard in order to reduce the processing activity required to meet high standards. Moreover, ZigBee and 6LoWPAN possess a pre-shared key along with a symmetrical cryptographic algorithm. For instance, 6LoWPAN uses RFC 4944 and RFC 6282 to segment IPv6 into 802.15.4.

4.4 Stack Size and Scalability:

Based upon stack size / packet overhead, it is adequate to debate that the 6LoWPAN is relatively scalable, leading to the consequence of it not needing extra header information. Seemingly advantageous, reducing packet overhands and providing more space for data. Typically, 6LoWPAN allows for 30KB when compared to ZigBee’s 90 KB.

5. Conclusion:

Web 3.0 and its applied ‘Internet of Things’ technology are growing areas of interest and considered as the futuristic vision of technology that will integrate the lives of people and people themselves with information technology. Such smart environments created by IoT offer wide areas of interest in research, in the various applied fields of human society, whether in health, education, enterprise and administration, social networking, or even leisure and entertainment. It is strongly debated that the automated environment embodied by the automation of services with digital technology will enhance the human experience, having implications in all fields of society to help in the effective communication between the different stakeholders, yet leaving us humans more enslaved by technology and its growing services, with effects needless to discuss. Thanks to developments in the field of WSN technologies such as RFID, we can now virtually imagine an entire world connected to the Internet to upgrade to the next level in global interconnection; Web 3.0.

Knowing that protocols are highly researched and relevant comparison studies already exist, many existing research papers regarding smart objects and their associated protocols were surveyed to construct decisive dimensions of the topic at hand. Reassuringly, the IoT market is very profitable and competitive, with a number of technologies providingidentical services using diverse methods with variable results.

It was noted that low-power consumption is of critical importance to these protocols and services, since they are aimed towards embedded devices. Technically, low-power consumption is achieved by the prolongation and maintenance of sleep states in order to idle devices, and restricting frame overhead costs such as headers to maximize data payload. Mobility is also critical, with most protocols supporting ad-hoc networks through the use of active routing algorithms that monitor hops between nodes and reorder and rearrange transmission paths.

This research also highlighted the fact that some protocols are showing success by aiming towards very specific purposes, such as NFC’s Point-to-Point data transfer on mobile devices. The dynamic perspective of this research leads to the belief that the spread of marketable devices with low-cost hardware will aidin accelerating the development of each set of protocols, further instituting their establishment within the market by aimingparticular device topologies.

Accessible existing research was used to compare and contrast the protocols ZigBee and 6LoWPAN in considerable depth. As previously discussed, both use the 802.15.4 standards as a mode of functionality, in addition to their free availability for use. Such protocols offer comparable services although ZigBee is presently more supported in the market than 6LoWPAN. Despite such variable fact, 6LoWPAN is widely deployed; being IP-based,making it favourable when connecting to the Internet, which is also based on the IP protocol suite.

6LoWPAN delivers interoperability through IPv6 interfaces, while ZigBee is more interoperable out of the two due to its use of adaptation layers, therefore, making it more adaptable when connecting with other heterogeneous standards. However, 6LoWPAN is considered more scalable due to its larger payloads and reduced overhead costs. As a final point, ZigBee is generally more suited towards smaller ad-hoc architectures, with such criterion being a major influence when deciding the adoption of a specific protocol.

Table 1: WSN standards and relevant network types for several wireless protocols.

Wireless Technology	Network Created	Relevant Standard
ANT	WPAN	Managed by Dynastream Innovations Inc.
BLE	WPAN	Currently managed by Special Interest Group (SIG), it is originally IEEE 802.15.1
IEEE 802.15.4 Based Motes	WPAN	IEEE 802.15.4
IrDA	Point-to-Point (PPP)	Managed by IrDA Industry-based Group
NFC	Point-to-Point (PPP)	ISO/IEC such as: ISO 13157
ZigBee	WPAN	IEEE 802.15.4

Table 2: A display of the approximate range and maximum power consumption of the chosen WSN/Web 3.0 standards (Mohammed H *et al*., 2012).

Wireless Technology	Approximate Range / m	Maximum Power Consumption / mA
ANT	10	17
BLE	50	12 – 15
IEEE 802.15.4 Based Motes	Technology-dependent (Configuration)	Receiving = 18.8 Transmitting = 17.6
IrDA	0.1 – 1	10
NFC	0.05	50
ZigBee	100 – 300	30 – 40

Table 3: The application throughput and latency various WSN/Web 3.0 standards (Tarbish R *et al*., 2013).

Wireless Technology	Application Throughput / kps	Latency / ms
ANT	20	Zero; with continuous scanning
BLE	305	2.5
IEEE 802.15.4 Based Motes	10 – 200	2 – 50
IrDA	100 – 200	25
NFC	424	Manufacture Specific
ZigBee	100	20 – 30

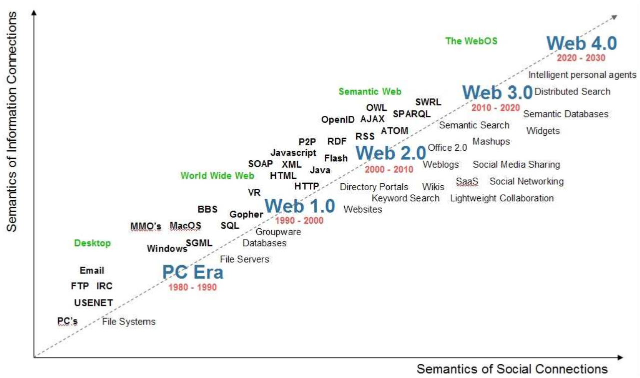

Fig. 1: The history and evolution of the Internet in five phases adopted from Radar Networks & Nova Spivack, www.radarnetworks.com.

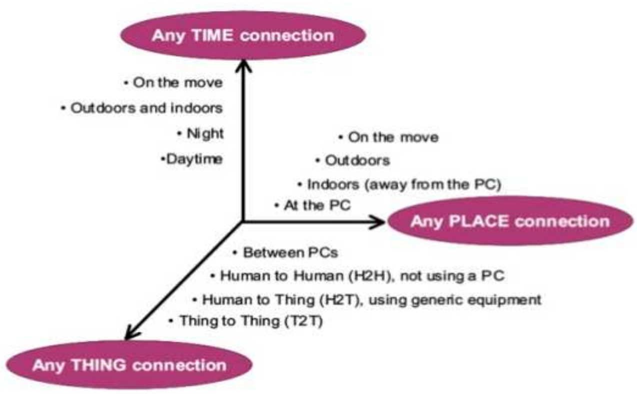

Fig. 2: Dimensions anticipating and forming the model of IoT. Adapted from Nomura Research Institute.

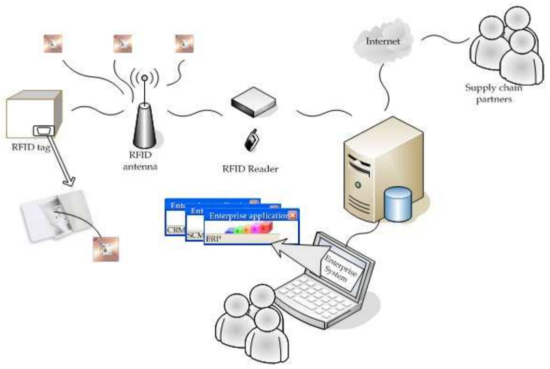

Fig. 3: Application of RFID networking architecture in enterprise to automate logistic tasks (Eurostat, 2009).

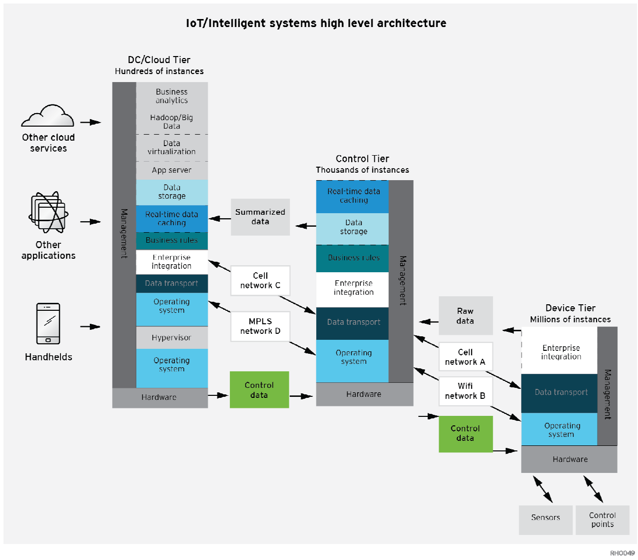

Fig. 4: The three tiers comprising the general IoT/Web 3.0 architecture (Sandor S., 2014).

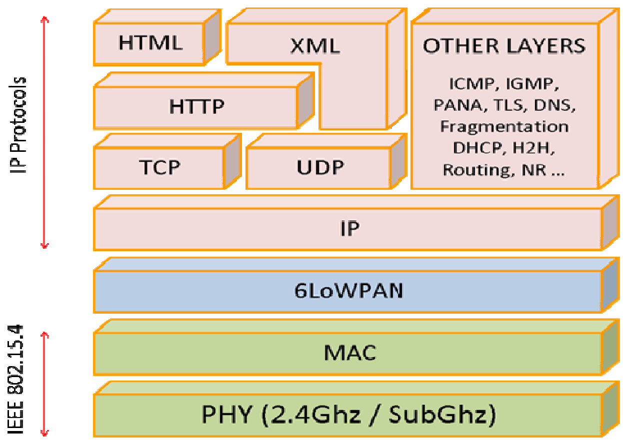

Fig. 5: A combined protocol stack for the ZigBee protocol including 6LoWPAN showing the networking layers of connection.

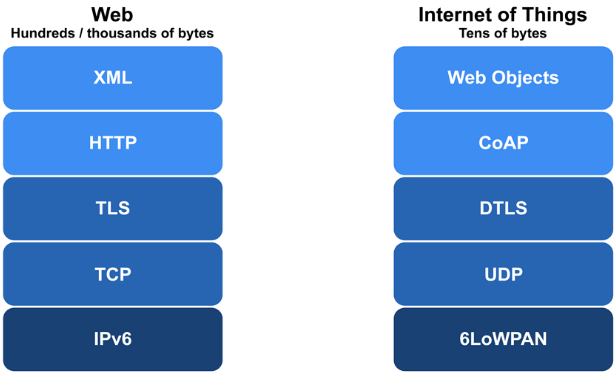

Fig. 6:A usual stack for the 6LoWPAN protocol commonly used with Web 3.0/ IoT platforms (Dunkels A *et al.*, 2014).

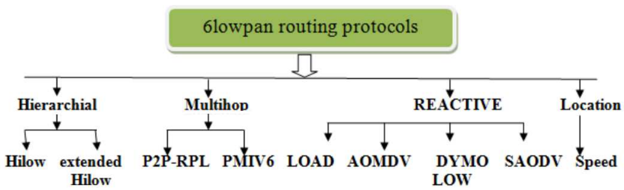

Fig. 7: Classification of 6lowpan routing protocols (Babu H, 2014).

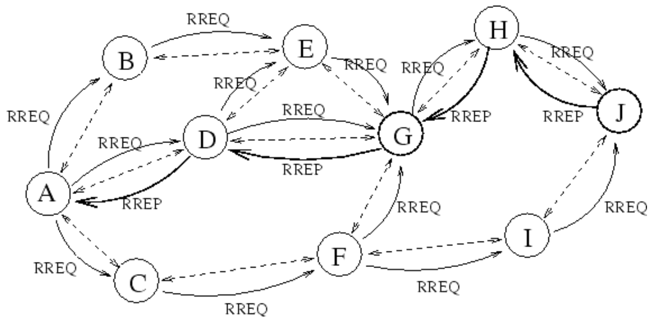

Fig. 8: The application of AODV routing protocol in anticipated Web 3.0 architectures using the existing architecture in WPAN (P Saraswala, 2013).

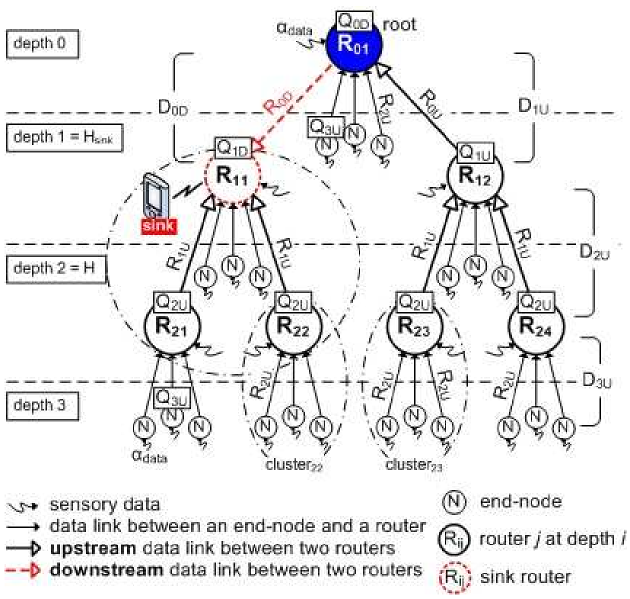

Fig. 9: Cluster-tree routing protocol in a typical PAN/WSN (P. Saraswala, 2013).

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