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Internet of Things for Enterprise: A Survey

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ABSTRACT

Novel Application and services designed with the Internet of things contemplate a future in enterprise, which allows to connect seamless Objects, Digital and physical devices to enlarge communication capabilities. IOT is more compatible to construct large scale enterprise with node and device heterogeneity, able to handling a large number of events generated simultaneously. Interoperability of the application and services can achieve by building context aware and probabilistic middleware of the IOT with the various level of heterogeneity. Modern IOT middleware proposal address WSN and not considered RFID, SCADA and M2M (Machine –to-Machine) into account. In this paper we investigated and gathered the requirements for IOT Middleware and briefly discussed about the limitations and benefits of existed middleware's. In addition, we highlighted open research challenges in research scope, Issues and further research directions.

Keywords:- RFID, SCADA, M2M

I. INTRODUCTION

IOT (*Internet of Things*) as an emerging technology, offering modern digital transform solutions to make applications (Healthcare, Auto mobile, Industries,) are reliable and scalable.IOT for the automobile offers various features like areTracking the location, traffic estimation, location next hop, monitors the movement of the vehicle. IOT health care offers state-of-the art of architecture, applications, industry trends, **e-health** solutions and Regulatory board norms for health care are discussed [1]. RFID (Radio frequency identification) is the existed platform offers solutions by to connect multiple devices [2]. IOT is the word formed with extension capability of RFID.IOT will form by connecting ultra-number of things and devices [3][4]. IOT is not only supporting the Healthcare and automobile and offers various other applications like Smart Homes, Medical aids, elderly assistance, energy management, mobile health care are explained in [5], [6], [7], [8], [9] and analyzed vertical markets to grow with horizontal integration between them in IOT applications require separate Operating systems which already available in the various flavors (Contiki,Brillo ,mbed ,RIOT ,FreeRTOS ,Embedded,OpenWSN ,TinyOS) discussed in [10]- [17] and illustrated in Table.1.Programming Languages for IOT middleware are well discussed in [18][19].

Fig.1 (Courtesy by Ala Al-Fuqaha at el [33]).

Fig.1 Vertical markets of IOT and Horizontal
Integration between them.

Operating System	Language Support	Minimum Memory (KB)	Event-based Programming	Multi-threading	Dynamic Memory
TinyOS	nesC	1	Yes	Partial	Yes
Contiki	C	2	Yes	Yes	Yes
LiteOS	C	4	Yes	Yes	Yes
Riot OS	C/C++	1.5	No	Yes	Yes
Android	Java	-	Yes	Yes	Yes

Table.1Operating System Usage in IOT Environment

Fig.2 illustrates the basic elements of IOT, namely SCADA, WSN (Wireless sensor Networks), RFID, M2M [20] [21] and also explained in detail in Fig.3.

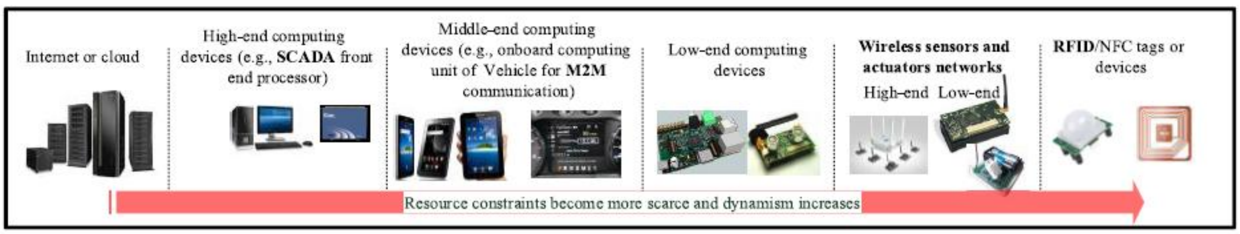

Fig.2 High Level Architecture for IOT elements

Fig.3 Low Level Architecture for IOT elements

Many existed IOT middleware's are Wireless sensor network centric approaches and out of theses some are not comprehensive [22], [23], [24] and many are not followed novelty [25], [26], [27]. [20] Perera et al identified gaps in between various existed IOT middleware's and analyzed no single existed middleware not providing complete WSN and IOT solution requirements. [25] [28] Bandyopadhyay et al. expresses important of middle ware do not included specific importantmiddleware [29], [30], [31].Zhou has presented only a conceptual view of a unified frameworkor IOT middleware based on service orientation and not included recent IOT middle ware [32]. IOT platform allows to aces big enterprise data systems like a big Data solution through the Hadoop programming [34], [35], [36].

II. BACKGROUND, IOT ARCHITECTURE, MIDDLEWARE REQUIREMENTS AND PROTOCOLS

2.1 BACKGROUND

IOT Application can be viewed in three ways 1) Knowledge Oriented 2) Things-oriented 3) Internet-oriented. IOT supports a consumer (Humans as HIOT) and as well as industries (IIOT) [37], [38], [39]. European research cluster of IOT (IERC) stated that IOT is technology, which allows the people and things can connect "Anyone,Anytime,anything,any place,any network and any service" [40], [41] andITU defined as "at any point of a time, anyone connect to any place and thing seamlessly" [42].

2.2 IOT ARCHITECTURE

IOT allows users to connect billions / trillions of heterogeneous devices seamless, so efficient layered architecture needed [43]. IOT-A project regulated the architecture standard [44]. initially IOT have a basic model (i.e. 3-tier model [45, [46]]) and later extended to 5-tier model recently proposed by cisco. Fig.4 illustrated the 3-ti3r and 5-tier IOT type applications haveobjects, Object abstract, Service management, Application and Business layers.

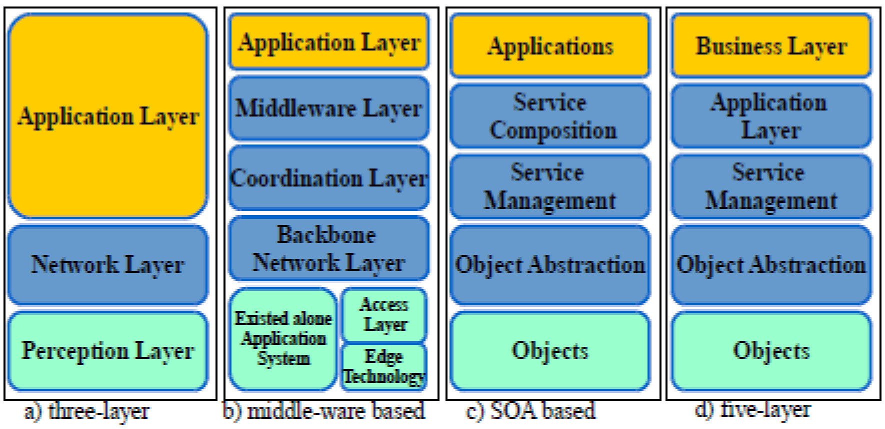

Fig.4 IOT Architecture.

2.3 CHARACTERISTICS OF IOT INFRASTRUCTURE

Every IOT infrastructure must have characteristics like Device heterogeneity, Resource Constrained, Event based interaction, Scalable event and network [47], [48], Dynamic topology, Location and Context aware [49], Intelligent [50], [51], web service and SOA oriented [52] and distributed.

2.4 CHARACTERISTICS OF IOT APPLICATIONS

IOT applications should have some basic characteristics like Wide application support (exhaustive, Non-exhaustive, Event Driven, Time driven), Real time Everything as a service (XAAS) [53], [54], [55] secured and manage Privacy [56].

2.5 MIDDLEWARE REQUIREMENTS

Middleware must abstract the toughness of the system software or hardware, allowing the application developer to allow to resolve the issues without the distraction of orthogonal concerns at the system or hardware level [57].

2.5.1 MIDDLEWARE SERVICE REQUIREMENTS

2.5.1.1 FUNCTIONAL REQUIREMENTS

Middleware services requirements can be classified into two, one is functional and another is Non-Functional Requirements. Every middleware must support functionally in terms of Connect discovery, data management, Resource management, Code and Event management.

2.5.1.2 Non-Functional Requirements

Non-Functional Requirements of the middleware are Scalability, Dynamic, Reliability, availability and privacy secure, popularity and easy to deployment.

2.5.2 Architectural Requirements

Architectural requirements of the middleware are Programming Abstraction (in terms of SQL Query [58], Context configuration with XML [59]), Interoperability [60], [61], Service based, Adaptive, Autonomous [62], [63], Context aware, Proactive and predictive [64].

2.6 Common Standards

2.6.1 Application Protocols

2.6.1.1 CoAP

CoAP[65-68] is an application protocols defines the standard in terms of (block-wise resource transport management, Resource discovery, Security, Interaction with HTTP protocol, Resource observation).

2.6.1.2 XMPP

XMPP[69, 70] is implemented by IETF which supports instant messaging applications (like Multi-part chatting, Voice and video calling, teleconference) and also works as Gateway/Bridging between foreign message.

2.6.1.3 MQTT

MQTT (Message Queue Telemetry Transport) founded in 1999 and regulated in 2013 at OASIS [71]. It's objective that connecting the network with embedded devices by interfaces and middleware and applications. It has 3 components namely broker, publisher, subscriber. Broker security done through authorizing the subscriber and publisher [72].

2.6.1.4 AMQP

AMQP (*Advanced Message Queuing Protocol*) [73] open application protocol which more suitable to support message oriented approaches.it requires TCP help to broadcast packets/ messages.

2.6.1.5DDS

DDS (*Data Distribution Service*) is works on publish /Subscribe approach forM2M communication developed by OMG [74]. DDS [75] points out that this protocol scales good when no of nodes increased. [76] MQTT and CoAP comparison done in terms of bandwidth usage and delay. [79] XMPP performance evaluation done and compare two light weight protocols [78] in terms of bandwidth usage and round trip time.

2.6.2 Service Discovery Protocols

Mainly this type of protocols offers the related to resources and services. mDNS (Multi cast DNS) and DNS-SD (Service Discovery) are two light weighted versions for IOT [80] [81].

2.6.3 Infrastructure Protocols

Based on IPv6 IETF designed a protocol to handle Resource-Constrained nodes called as ROLL [82], [83]. Routing of the nodes illustrated by DODANG, which is the core of RPL. DODANG root elements handle both request and responses in terms of Receipts [84].6LowPan [85] is another protocol developed by IETF in 2007 and compatible for IPV6 Network. IEEE 802.15.4 [86] specify MAC and Physical layer's sublayer for LR-WPAN (low rate Wireless private area network). Blue tooth [87] low energy protocol one more good for IOT Applications. BLE supports V-to-V communication [88] as well as for WSN [89] and also compared with Zig-Bee at [90]. EPCGlobal [91] is powered with RFID and used to identify the items under supply chain management. It is very useful track ID's and Service Discovery [92] good for future IOT based applications offers interoperability, reliability, Openness, Scalability and sustainability. LTE-A [93] very much fit for machine type communication suitable for Smart cities, where long term of durability expected.Z-Wave [94] is suitable for Low power wireless communication and small scale enterprise applications. Table.2. illustrated the protocol characteristics.

PHY Protocol	Spreading Technique	Radio Band (MHz)	MAC Access	Data Rate (bps)	Scalability
IEEE 802.15.4	DSSS	868/ 915/ 2400	TDMA, CSMA/CA	20/ 40/ 250 K	65K nodes
BLE	FHSS	2400	TDMA	1024 K	5917 slaves
EPCglobal	DS-CDMA	860~960	ALOHA	Varies 5~640 K	-
LTE-A	Multiple CC	varies	OFDMA	1G (up), 500M (down)	-
Z-Wave	-	868/908/ 2400	CSMA/CA	40K	232 nodes

Table.2. Characteristics of Protocols

2.6.4 OTHER PROTOCOLS

Codo [95], IEEE 1905.1 [97] Event guard [98], QUIP [99] are other protocols. Codo offers security at file system and especially designed for Contiki OS and IPsec for 6LowWPAN. IEEE 1905.1 supports for heterogeneous technology [96] based smart home applications. Eventguard and QUIP used for encryption and authentication purpose.

III. EXISTED MIDDLEWARE& PLATFORMS

IOT applications are very big enterprise applications usually, which requires more number of integration from one layer to another layer. Architecture constructed based on several layer which require for enterprise. Each layer performs a unique role and passes the information from one layer to another in either upward/ Downward direction. The middleware works like an interface between the layer where platform supports all the layers together. we exclusively collected and compared previous existed middleware approaches in terms of Functional, Non-Functional and architectural requirements in the below

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Event-based approach																				
Hermes [100]					NI		NI				NI									
EMMA [101]							NI				NI				N					
GREEN [102]							NI		NI		NI				N	N				
RUNES [103]							N	NI	NI		N									
PRISMA [104]							NI				NI					N				
SensorBus [105]			N		NI		NI	NI	NI		NI					NI	NI			
Mires [106]							NI				NI				N	N	NI			

Table.3 Event-Based Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Service-oriented approach																				
Hydra [107]					N			NI	NI		N					NI				
Sensewrap [108]		NI	NI		N			NI	NI		N				NI	NI				
MUSIC [109]			N	N	N		N			NI	N								N	
TinySOA [110]				N	N		N	N	N		N				N	N				
SOCRADES [111]			NI		N			NI	NI		N								NI	
SENSEI [112]				N	N			NI	NI							NI			NI	
ubiSOAP [113]			NI		N		N		N	NI	N				N	NI				
Servilla [114]							N		NI	NI	N				N	NI				
KASOM [115]			N		N						NI					NI				
CHOReOS [116]					N		NI		NI	NI	N					NI			N	
MOSDEN [117]				NI	N		N		N	NI	N					NI				
Xively [118]				NI	NI				N		N					NI			NI	
CarrIoT [119]				NI	NI				NI		NI				N	NI				
Echelon [120]				NI	NI				NI		NI				N	NI				

Table.4 Service Oriented Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
VM approach																				
Mate [121]							NI				NI									
VM* [122]							NI				NI				NI					
Melete [123]								NI									NI	NI		
MagnetOS [124]							NI				NI				NI					
Squawk [125]				NI			NI	NI			NI				NI		NI	NI		
Sensorware [126]							NI	NI	NI		NI									
Extended Mate [127]							NI				NI									
DVM [128]							NI				NI				N		N			
DAViM [129]							NI				NI									
SwissQM [130]											NI				N					
TinyVM [131]	NI	NI		NI	NI	NI	NI	NI	NI	NI	NI			NI	NI	NI	NI	NI		
TinyReef [132]	NI	N					NI	NI			NI			NI	NI	NI	NI	NI		

Table.5 Virtual Machine Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Agent-based approach																				
Impala [133]								N												
Smart messages [134]									NI		N				N				NI	
ActorNet [135]							NI	NI			NI				N					
Agilla [136]							N				N									
Ubiware [137]											N									
UbiROAD [138]									NI				NI							
AFME [139]							NI		N		NI									
MAPS [140]							NI	NI			NI				N					
MASPOT [141]							NI				NI									
TinyMAPS [142]							NI				NI									

Table.6 Agent-Based Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Tuple-space approach																				
IME [143]							N	N			NI					N	N			
TeenyLIME [144]							N	N			NI					N	NI			
TinyLIME [145]								N								N	N			
TS-Mid [146]					N	N	NI				NI									
A3-TAG [147]					N		NI				NI									

Table.7 Tuple-space Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Database approach																				
SINA [148]					N		N	N	N		N			N	N			N		
COUGAR [149]					N				NI					N	N	N	NI	N		
IrisNet [150]									N					N	N	N	N			
Sensation [151]					N		N		NI		N						N	NI	NI	
TinyDB [152]					NI		N	N	N		N			NI	NI	N		N		
GSN [153]									NI		N			NI	NI	NI				
KSpot± [154]				N	N				NI		N				N		N	NI		
HyCache [155]				N	N		NI	N			NI			NI	NI	NI	NI	N	N	

Table.8 Database Approach

	Functional requirements					Non-Functional Requirements							Architectural Requirements							
	RD	RM	DM	EM	CM	SCA	SEC	AVA	REL	RT	PRI	POP	ABS	INTE	CA	AUT	ADA	SB	LW	DIS
Application-specific approach																				
AutoSec [156]							NI				NI		N							
Adaptive middleware [157]							NI						N							
MiLAN [158]							NI				NI		N							
TinyCubus [159]							N				N									
MidFusion [160]							NI				NI		N							

Table.9 Application-specific Approach

Designing and development of IOT Platforms/Test beds are must satisfy the Heterogeneity [161] of the IOT which supports multiple applications instead of addressing single applications [162]., e.g. Wireless sensor networks or RFID.The scope and Architecture of IOT Test beds illustrated in Fig.5 and IOT Testbeds survey presented in table 10.

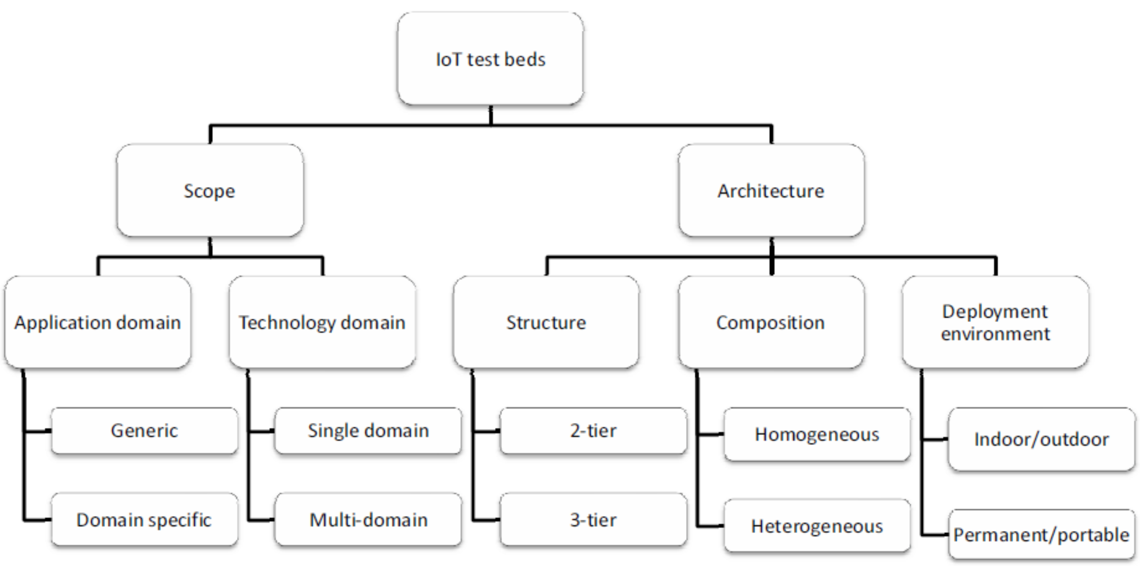

Fig.5 Architecture and Scope of the IOT Test Beds

Test Bed	Cloud Orienetd	Nature	Auto Device Integration	Device Heterogenity	Service Discovery	Gateway	Mobility	Programming Approach	Third pary Inclusive	security	Data Storage	Dynamic device Adoption	Optimization
CitySense [163]	N	Server	N	N	N	NI	N	Network Aware	N	2 LEVEL		N	N
SensorCloud[164]		PaaS		PROPRITERY	N		L	RESTful	N	TLS		L	SOME DATA AGGREGATION
EveryWare[165]		M2M Paas			N			RESTful				L	OPTIMIZED DATA TRANSPORT PROTOCOL
Thingwrox[166]		M2M Paas		Http based		N		Model-Based	N			L	
ThingSquare[167]		Mesh		Specialised			L	RESTful	N	TLS/SSL	Temporary	L	
Axeda[168]		M2M Paas						RESTful	N	USER BASED		L	
Xively[169]		PaaS		Http based		N		RESTful	N	TLS/SSL		N	
EvryThng[170]		M2M Paas		Http based		N		RESTful	N	FINE GRAINED		L	
IFTTT[171]		SaaS		Http based		N		Rule based	N	NO STORAGE	N	N	
SOCRADES[172]	N	Server				NI	L	WS based SOA	N	SECURED		L	
TerraSwarm[173]		OS						SOA	N			L	SOME DATA AGGREGATION
CEB[174]		PaaS					L	Extended SODA		N	Temporary		Extensive Optimized

Table.10 Comparison of the IOT Test Beds

IV. QOS CURRENT RESEARCH CHALLENGES

The existed middleware and Testbeds addressed lot of IOT requirements, whereas still IOT have many open challenges like context-awareness, security, interoperability, scalability, reliability and dynamic heterogeneity, service discovery. The functional requirement handles Resource, data, code and event managements. Non-functional requirements mainly focus on QOS (Accuracy,dynamic,network extension,integrity,secure deployments, availability, popularity)and Architectural Requirements (Programming abstraction, Interoperability, Service-based, Adaptive, Context-awareness and autonomous behavior).

V. CONCLUSION &FUTURE TRENDS

Testbeds and Middleware are requiring to develop IOT based diverse applications and services easily. This paper presented the holistic view of existed approaches related to IOT.In doing this, we briefly discussed about background, IOT Architecture, IOT Common Standards, IOT Key characteristics, applications,a comprehensive survey of existed middleware and Test beds. Survey exclusively discussed about existed middleware based on their design approaches (event-based, service-oriented, agent-based, tuple-space, VM-based, database-oriented, and application-specific). Each Middleware proposals expressed in terms of functional, Non-Functional and Architectural requirements. At last we discussed about open research challenges, issues and future scope of implementation.

In spite of the fact that the current middleware arrangements address numerous necessities related with middleware in IOTs, a few prerequisites and related research issues remain generally unexplored, for example, versatile and dynamic asset disclosure furthermore, structure, framework wide adaptability, unwavering quality, security furthermore, protection, interoperability, incorporation of knowledge, and setting mindfulness. There is the critical extension for future work in these ranges. We also identified few more research trends like Social channel integration with IOT, developing green IOT bases Apps, AI (Artificial Intelligence) with IOT and IOT with Cloud applications.

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