Performance, Reliability and Scalability for IoT

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Abstract— So-called IoT, based on use of enabling technologies like 5G, Wi-Fi, BT, NFC, RFID, IPv6 as well as being widely applied for sensor networks, robots, Wearable and Cyber-PHY, invades rapidly to our every day.

There are a lot of apps and software platforms to IoT support. However, a most important problem of QoS optimization, which lays in Performance, Reliability and Scalability for IoT, is not yet solved. The extended Internet of the future needs these solutions based on the cooperation between fog and clouds with delegating of the analytics blocks via agents, adaptive interfaces and protocols.

The next problem is as follows: IoT can generate large arrays of unmanaged, weakly-structured, and non-configured data of various types, known as "Big Data".

The given papers deals with the both problems. A special problem is Security and Privacy in potentially "dangerous" IoT-scenarios. Anyway, this subject needs as special discussion for risks evaluation and cooperative intrusion detection.

Some advanced approaches for optimization of Performance, Reliability and Scalability for IoT-solutions are offered within the paper. The paper discusses the Best Practises and Case Studies aimed to solution of the established problems.

***Index Terms*— Performance, Reliability and Scalability, QoS for IoT, Cloud and Fog, Robotics, Industry 4.0, 5G, Big Data Analytics, Machine Learning.**

I. Motivation and the Aims

The digital technologies and platforms conqueror the industrial and social processes, as well as our every day. They are depicted in Fig. 1. As basic platforms clouds, fog and data mining are used. The modern technologies are as follows: Blockchain, Machine Learning, IoT, Robotics, 5G. They involve new application fields, which require higher QoS, advanced Performance, Reliability and Scalability. Such applications must be secured because invading the industrial processes, every day workflows and, frequently, the privacy of humans. The apps, which are based on, are often very resource and energy consuming. Therefore, the requirements for IoT and other digital technologies have to be formulated with focus on providing of the above-mentioned criteria.

The following aims are targeted with the paper:

1. Optimization in the use of virtual components based on clouds and fog.
2. Increasing of performance, reliability and scalability for IoT-solutions.
3. Optimal re-configuring and management of Big Data analytics via cloud and fog co-operation.
4. Management analytics blocks can efficiently handle redundant data from IoT and robots.
5. In order to reduce the complexity of the acquired data, the up-to-date Machine Learning (ML) methods are used as an important part of the analytic blocks.

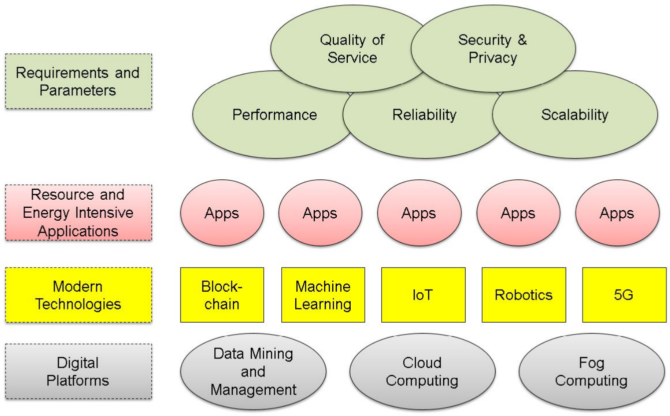

Fig. 1. Motivation and demarcations

The further paper content was built as follows:

1. Motivation and the aims of the paper are established (this Section I).
2. State-of-the-art approaches to performance optimization and typical QoS requirements are discussed (Section II).
3. Advanced analytics placement options on example of Cyber-PHY and robotics (cloud and fog based) are offered. The approaches are aimed to increasing of performance, reliability and scalability for IoT-scenarios (Section III).
4. Big Data shortcomings for important IoT areas are discussed (Section IV) as well as the solution approaches (Section V) offered. These can be partially ML based.
5. Finalising, conclusions have been done and outlook provided (Section VI).

II. Performance Optimization. QoS Parameters

Modern networking uses widely management of QoS-parameters aimed to Performance, Reliability and Scalability optimization [1, 2]. So-called IoT is based nowadays on IPv6. This brings more freedom in addressing of immense quantity of available devices: sensors piconets, Embedded, Wearable, Cyber-PHY, robots, intelligent stuff etc. Huge as well as heterogeneous data volumes (approx. 100PB to 100EByte) are acquired additionally causing Big Data shortcomings [3, 15]. The processing and upload- and download-functionality for sensor piconets and robotics is offered via Cloud and Fog systems in their cooperation.

The mostly used communication models are as follows (Fig. 2). The both possess pro and cons regarding to the communication performance, reliability and scalability in mobile and heterogeneous networking. The alone functionality delegation to the servers can lead also to the shortcomings for the mentioned topics. The models for performance optimization under use of classical methods are depicted Fig. 3.

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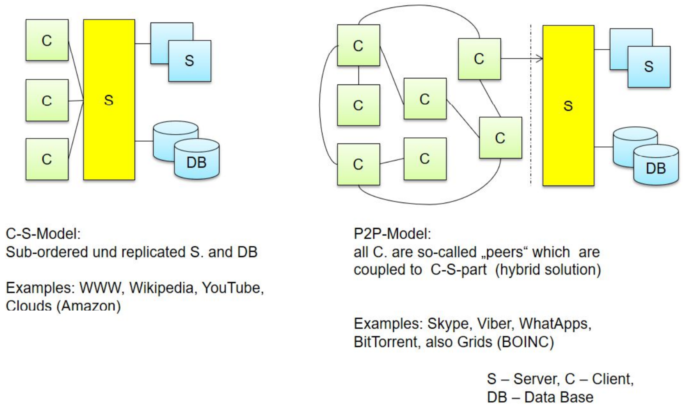

Fig. 2. The mostly used communication models

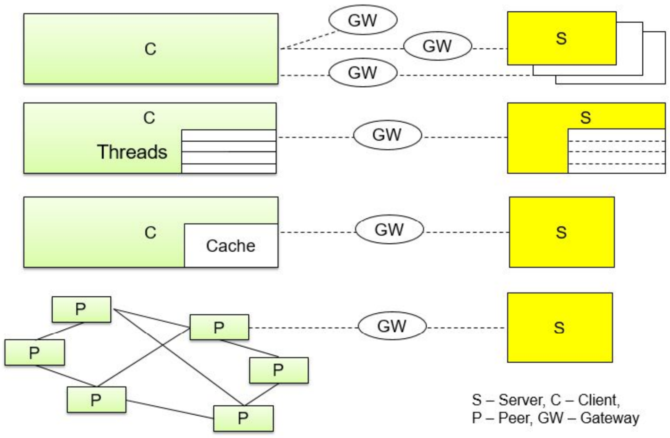

Fig. 3. Commonly used classical methods for the server-based and server-less apps

These methods are as follows [1, 2, 21]:
(1) Multi-threading.
(2) Replication.
(3) Caching on Client.
(4) n-tier and use of proxies and gateways (GW).
(5) highly-distributed Peer-2-Peer (P2P) as well as
(6) further empiric rules (refer Table I).

The small intelligent nodes in IoT-scenarios communicate via energy-autarky gateways with the capable server part. The considered approaches are able to increase the performance, reliability and scalability in desktop applications and IoT both. Which further approaches can be applicable? Let's discuss how these affect the following QoS criteria like throughput, response time, probability of failure, availability, and reliability? Table I represents the influence if the listed approaches on the QoS parameters within an IoT system in detail.

Further performance optimization can be reached via the analytics migration into the clouds. The cloud-centric systems can discharge the energy-critical mobile nodes (Fig. 4).

A good balance between C and S parts brings use of fog systems. The sensors, robots, intelligent stuff as well as further Cyber-PHY operate partially autonomously (SLMA – server-less mobile apps). Such autarky is possible via energy-efficient communication protocols and software (cp. AutomationML, OPC UA, MQTT, AMQP).

TABLE I. PERFORMANCE OPTIMIZATION [1, 2]

Approaches for QoS	Max. throughput	Minimal reaction on time	Reduced downtime	Better availability	Better scalability	More reliable
Multi-threading	x	o		o	x	
Replication			x	x	x	x
Caching on Client		x		o	x	o
n-tier	o	o		o	x	x
Use of proxies and gateways	o			x	x	x
Peer-2-Peer		x		x	x	
Further empiric rules	x		o	x	o	o
Notice:	***o – partially compliant***		***x – conditionally compliant***			

An explanation of such important parameter like reliability, which is expressed per average downtime Tdown, is given in Table II. The following classes 1 – 7 of service availability are given in regard to so-called sidereal year (365.24 days) under considering of the leap years. The given representation is based on [1, 2] and depicts the services from the 90%-reliable IoT systems and up to the error resistant systems.

Which further specifics can be used for the analytic placement for the performance and scalability in IoT and robotics? The next section deals with the question.

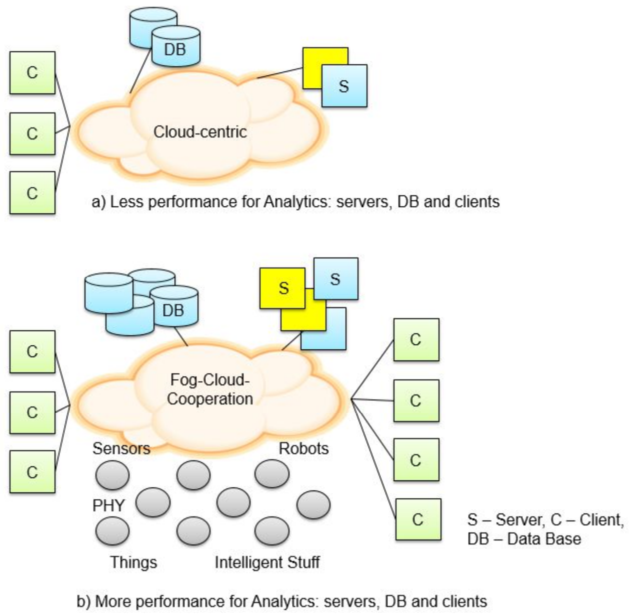

Fig. 4. New approach: Performance optimization due to migration in clouds and fogs

TABLE II. AVAILABILITY BOUNDARIES AND CLASSES [1, 2, 20]

#	Availability and annual downtimes			
	Yearly availability,%	***Downtime yearly, Tdown***	***Units***	***Availability classes***
1	90	36,52	days	1 – reliable up to 90%
2	95	18,26	days	
3	98	7,30	days	
4	99	3,65	days	2 – stable
5	99,5	1,83	days	
6	99,8	17,53	h	
7	99,9	8,77	h	3 – available
8	99,95	4,38	h	
9	99,99	52,59	min	4 – highly available
10	99,999	5,26	min	5 – insensitive to errors
11	99,9999	31,56	sec	6 – fault tolerant
12	99,99999	3,16	sec	7 – error resistant
	Average sidereal year	365.24	in days	(with leap years)

III. ANALYTIC PLACEMENT FOR THE PERFORMANCE AND SCALABILITY

The up-date highly-distributed apps (desktop as well as mobile) are characterized via multi-layer horizontal and vertical architecture. These layers can be as follows:

1. PHY world and hardware.
2. Software with interfaces (heterogeneous and adaptive).
3. Middleware components and web services.
4. Analytic blocks and mobile agents.

The layers and tiers are combined and balanced between client, cloud and fog part considering the QoS parameters like performance (throughput, response time), reliability (probability of failure, availability) and scalability too.

As appropriate examples OPC UA (OPC Unified Architecture) and programming framework, standardized by IEC 62541-2015 [12], as well as ROS (Robot OS) and programming framework [13] can be considered.

A. OPC UA

The OPC UA specification as well as the based framework for IoT and Embedded is a multi-part specification and consists of the following parts, layers and tiers as it was depicted in Fig. 5:

- Concepts, Security Model, Address Space Model
- Services, Information Model, Mappings
- Profiles, DA (Data Access), AC (Alarms and Conditions), Prog (Programs), HA (Historical Access)
- Discovery, Aggregates, PubSub.

The following bus formats can be used:

- EDDL (Electronic Device Description Language)
- ISA Bus (Industry Standard Architecture)
- Profibus as well as further fieldbus formats.

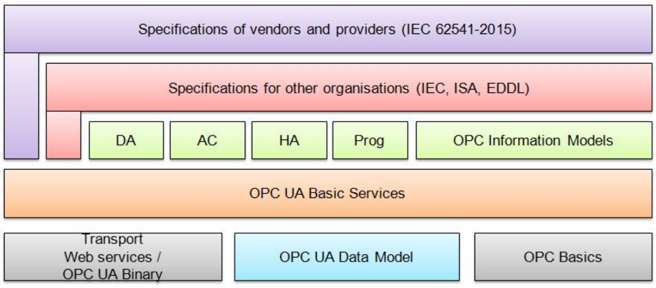

Fig. 5. OPC UA Architecture

B. ROS

The advantages of this OS are as the follows: fault-tolerance, reduced development complexity, availability of the examples on functionality and usage, documents and DB, video streams with tutorials, navigation via way-point navigation and location tracking [11 – 14]. The system is also configured to face recognition and sample calibration (Fig. 6).

Robot Operating System (ROS)	A FW with OS properties
SLMA: C++, Python, GUI	Autonomous client parts and GUI mostly, the server parts are mostly relatively small
Message Queuing Layer	Message exchange between the programmes and components
SOA Layer	SOAP and REST Web Services
Components and Middleware	Frequently used functions and communication components
Package Layer	APIs and Package Management
Programme Libraries	Use and robot SW deployment
OS Kernel Layer	Linux, Mac OS (experimental), MS Windows (rudimentary)
Device Layer	PHY device drivers
HAL	HW Abstraction Layer
Hardware	PHY-environment

Fig. 6. ROS Architecture

C. Advanced Architectures

The IoT and robotic applications can be classified into three following groups (Fig. 7). Therefore, we are talking about replaceable and customizable IoT and robotic algorithms in various fields of application (industry, medicine, communication and telecommunication, entertainment) which can acquire, then process and retrieve voluminous heterogenic Big Data in the given area [4 – 10].

They must be able to solve the problem of QoS optimization (performance, scalability, reliability) as well as Big Data shortcomings in better way due to intelligent distribution of the Data Analytics:

(1) Conventional IoT and robots.
(2) Cloud-Centric IoT and robots.
(3) Distributed (Fog-Cloud-cooperating) robots.

Only the cloud-centric solution (2) and further distributed, fog-cloud-cooperating solution (3) both are able to overcome the discussed problems in full measure. The analytic blocks,

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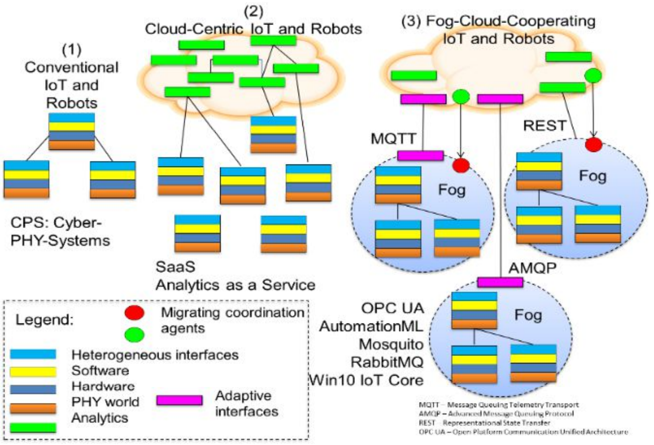

Fig. 7. Three communication ways to increase the performance, reliability and scalability

migration agents as well as further adaptive interfaces are delegated to the clouds and, possibly, after pre-processing and clustering backwards to the so-called "fog" under use of the mentioned solutions and protocols. The virtual analytical components (middleware, web services, and mobile software agents) are placed in the cloud and fog environment. Virtual cloud and fog solutions contain software components for the robots that implement reboot-able (virtual) business processes. The future robotics platforms must be conceived and designed under considering of the listed positions too (Fig. 8).

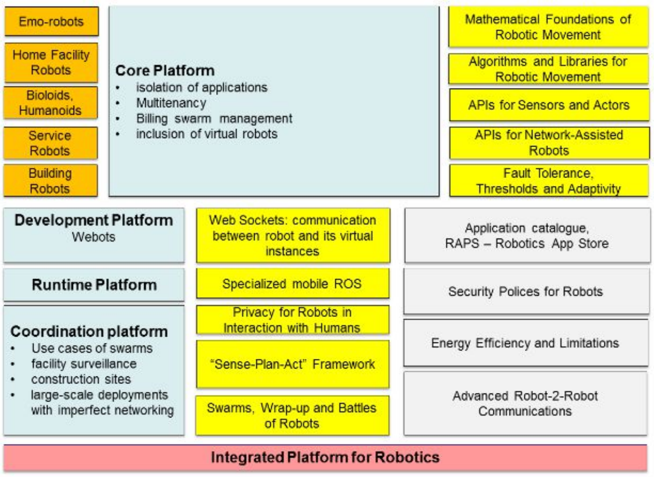

Fig. 8. The properties of the future robotics platforms

IV. BIG DATA

Thus, the typical sampling, survey and accumulation models in IoT-scenarios can lead to necessity of solving of Big Data shortcomings. A typical data acquisition and evaluation model is shown in Fig. 9. Mostly, the collected data are large unstructured and unmanaged.

Depending on the event frequency, the event driven, periodically, permanent, and the behaviour of the sensors (push, pull), a sensor survey and data accumulation are performed. Let's a WSN consists of 15000 sensors. Each sensor can transfer a short telegram up to 100 Bits.

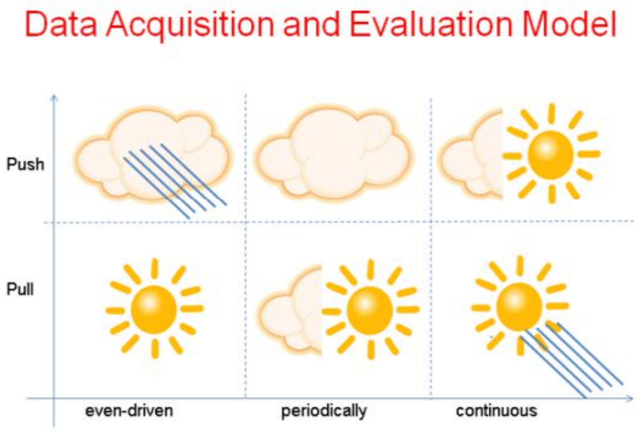

Fig. 9. Typical data acquisition and evaluation model

Thereby:

- The survey for each sensor is conducted 20 times per hour: 2000 Bits/h
- x 24h = 48000Bits/daily = 6000 Bytes/daily for each sensor
- In general, an average sensor wireless network accumulates experimental data for 3 years x 365 days:
- x 365 x 3 ~ 6.57 MB for each of the sensors
- The overall-data for the mentioned network: 6.57MBytes x 15000 sensors ~ 100 GB of raw data!

Further research of the data accumulated in this way can be carried out by manual and automated methods both (Fig. 10). As a result of such research data evaluation the following common documents can be issued under use of the depicted tools [1, 2, 15]:

1. Management Template.
2. Production Report.
3. Error Report.
4. Fault Forecast.
5. Feedback Recognition.

Big Data Management and Analytics helps to overcome the problem of acquirement of immense amounts of unmanaged and unstructured data. The IoT sources of unmanaged and unstructured data can be as follows [15 – 19]:

- Industrial data and navigation data (GPS, Galileo)
- Data from sensors and production capacities (Smart Manufacturing)
- Power and renewable energy stations (data for smart metering)
- Traffic and telemetric data (IoT)
- Robotics data (navigation, sensing, measurements)
- Collected personal data of citizens (NFC, BT) and much more.

In the conditions of modern industrial development, so-called "Industry 4.0" there are even more "Big Data" sources: home automation, patient health data, M2M etc. The mobile networks and aps for the 5G will definitely take an active part in the process of receiving and processing of large data amounts [1, 2] at very small latency (under 1 ms) too.

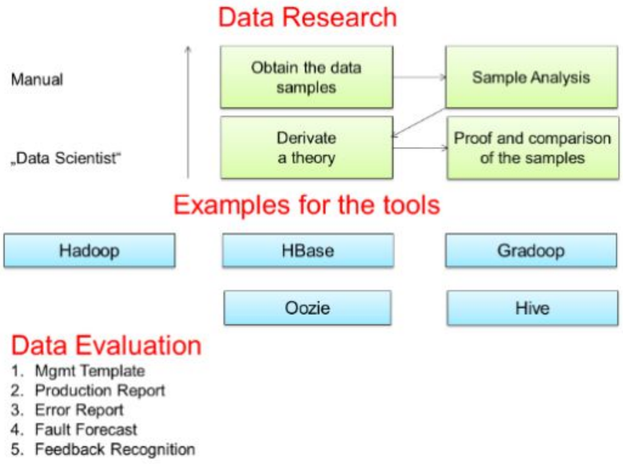

Fig. 10. Data Analytics: Manual and Automated

V. MACHINE LEARNING: WHAT IS IT?

The overcoming of myths and misconceptions is possible due to use of Machine Learning (ML). The (cloud-based) ML system enables artificial creation of knowledge from the obtained voluminous experimental data in background mode. An artificial system is "learned" from samples and examples and can summarize them after the completion of the study and evaluation (training) phase. The ML system recognizes templates and trends in research data. Thus, the ML (cloud) system can also evaluate data on representativeness and compliance.

Often the data research cannot be completely studied or their trends recognized due to the complexity and heterogeneity. The future transition "Big Data – Smart Data" is given in Fig. 11.

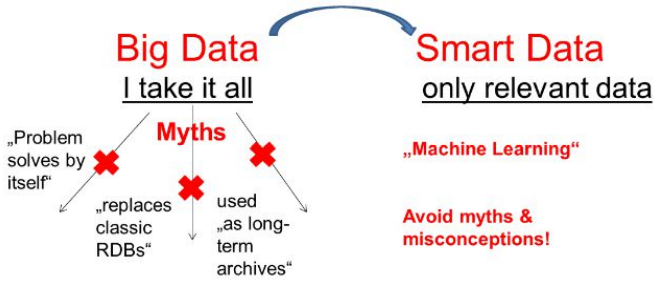

Fig. 11. Transition "Big Data – Smart Data"

Such analytic methods for ML use frequently the following approaches:

- ML based on ontologies
- ML based on FKB (Fuzzy Knowledge Bases).

The case studies on the above-mentioned subjects are offered in [15 – 19].

VI. CONCLUSIONS AND OUTLOOK

1. IoT-scenarios need nowadays the efficient access and management models under considering of the QoS parameters and low-energy-criteria.
2. Some classical as well as the advanced approaches to the optimization of Performance, Reliability and Scalability for IoT solutions were analysed.
3. The extended Internet of the future needs these solutions based on the cooperation between fog and clouds with efficient delegating of the analytics blocks via agents, adaptive interfaces and protocols.
4. The given work is also dedicated to Big Data sources and solutions in modern IoT issues. The best practices and case studies on Big Data and ML were discussed. The given papers deals with the both problems.
5. This work can be qualified as a "work-in-progress". The authors try to find new efficient method combinations to overcome the above-mentioned problems.
6. The aspects of Security and Privacy in such potentially "dangerous" IoT-scenarios need a special considering for risks evaluation and cooperative intrusion detection with a separated research.

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