The Impact of Digital Transformation on Technological Trends regarding IoT and Smart Systems

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Abstract. The present time is the time of digital transformation. New smart or intelligent devices and technologies influence our everyday life and have a great impact on our environment. Such paradigms as Internet of Things (IoT) and Smart Systems are also unavoidable undergoing changes and modifications. Especially the domain of Smart Cities is getting more and more attention and is benefiting from the outcomes of digital transformation. In this paper we focus on the evolution of technologies in this fields and provide an overview over a selection of numerous applications.

Keywords: Digital Transformation, Big Data, Business Analytics, IoT, Smart Systems.

1 Introduction

Digital Transformation, Digitization, Internet of Things (IoT), Smart Cities, Smart Systems and Big Data are some of the most discussed topics in recent years. Hardly anybody today does not possess a smartphone or some smart devices. Many activities and events private as well as public are digitally supported and displayed. As the critical mass of users has increased, many technologies have become important to business and government as well. Cities, on the other hand, are still not very advanced, except for a few exceptional projects. There is a lot of potential in the use of (smart) digital technologies, especially regarding big data.

On the other hand, digital support also involves new challenges. For example, the monitoring of the entire transport network brings immense benefits to public safety and simplifies everyday life for individuals through real-time reporting of congestion or accidents. However, concepts must also be developed to protect this data and personal information. This paper addresses the evolution of big data architecture, IoT and smart urban environment and highlights some of the challenges, but does not discuss legal implications or privacy issues.

Along with the progress of digital transformation a new dimension arises in the way how people interact with *things* in their surrounding environment. This evolution reveals a whole new area of research challenges and emerging technologies, as cumulated by Gartner [20] and presented in Fig. 1.

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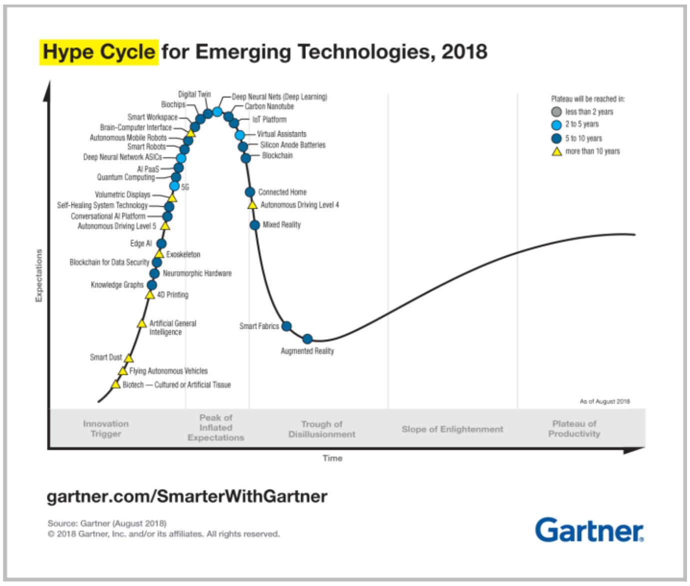

Fig. 1. Hype Cycle for Emerging Technologies [20].

The objective of this paper is to give an overview on changes and modifications of some selected important concepts and technologies as an implication of the digital transformation progress.

The next section describes at first briefly some of the most commonly used frameworks for processing big data. Then, the evolution tendency of IoT and Software-defined Systems is presented, followed by some selected trends in the area of smart cities.

2 Big Data Architecture

Big Data is one of the most discussed topics in the past and nowadays. The amount of produced and stored data from our environment, social networks or business sector is increasing every day. The requirements of big data applications are often described using the five V's: volume, variety, velocity, veracity and value [1]. There is no clear line, how much volume, variety etc. the data needs to have in order to be called 'Big Data'. But it is often considered that a data problem falls in the category if storing and processing of the data requires special tooling and thinking regarding the mentioned dimensions.

The challenge regarding big data is not anymore to collect and store data, but to analyze it efficiently and to extract its value. This leads to complex workflows, which require systems built for big data processing. One option for such workflows is to use projects from the Hadoop Ecosystem [14].

Apache Hadoop was initially introduced in 2007 as an open source implementation of MapReduce processing engine linked with a distributed file system. Since then it has developed into a collection of more than 100 projects related to every step of a big data workflow, including data collection, storage, processing, and much more.

The whole ecosystem is based on HDFS (Hadoop Distributed File System) and a framework for job scheduling and cluster resource management YARN (Yet Another Resource Negotiator). In the following some data processing engines are listed that are often used to develop analytic workflows for big data.

Apache Spark.
Apache Spark applications range from finance to scientific data processing and combine libraries for SQL, machine learning, and graphs. Spark has a similar programming model to MapReduce but extends it with a data-sharing abstraction called resilient distributed datasets, or RDDs. Spark is most commonly used with cluster file systems like HDFS and key-value stores like S3 or Cassandra. It can also connect with Apache Hive as a data catalog. Spark supports batch and stream processing [15].

Apache Storm
Apache Storm is a free and open source distributed real-time computation system. Storm uses streams for real-time processing and can be used almost with any programming language.

H2O
H2O is an open source framework that provides a parallel processing engine, analytics, math, and machine learning libraries, along with data preprocessing and evaluation tools. Additionally, H2O offers a web-based user interface, making learning tasks more accessible to users who may not have strong programming experience. The framework supports Java, R, Python, and Scala. In addition to its native processing engine, there is also Sparkling Water, which integrates Spark and Spark Streaming into H2O. H2O4GPU uses GPU computation to speed-up on model training time and inference time.

TensorFlow
TensorFlow is an open source software library for numerical computation using data flow graphs. Nodes in the graph represent mathematical operations, while the graph edges represent the multidimensional data arrays (tensors) communicating between them. TensorFlow was originally developed by researchers and engineers from the Google Brain Team for the purposes of conducting machine learning and deep neural networks research. TensorFlow is a mighty tool for analysis and processing of big data.

Apache Kafka
Apache Kafka is a distributed publish-subscribe message delivery system. It is characterized by being highly scalable, like it can scale to a large number of data sources simultaneously sending data at high rates, and reliable, since it is fault tolerant against

failing of computing machines (no data loss). Moreover, it is a powerful tool for building real-time data pipelines with high throughput and low latencies [16].

Another advantage of Kafka is that it guarantees at-least-one delivery of data from producers to consumers. A topic can be divided into several partitions that are located across different brokers which leads to Kafka's capability of delivering a large volume of messages simultaneously [17].

3 IoT and Software-Defined Systems

With the emergence of a new generation of cheaper and smaller wireless devices and numerous technologies including sensors, actuators, embedded and cloud computing, many things are becoming wirelessly connected to the Internet. Thus, the number and variety of devices that are used in this way has increased enormously. Such devices can vary in many aspects, e.g. in size, computing resources, operating mode, network technologies, protocols, usage scenario etc.

This concept is broadly known as the Internet of Things (IoT). In [2] the IoT is defined as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

Use cases in the IoT vary from home safety and management system, smart electricity monitoring in electricity grids, in-car system from road traffic to health monitoring and disaster management.

The concepts of IoT Architecture are broadly discussed in literature. In our previous research [13] we presented many aspects of IoT technology in detail. For further information, we refer to [3] and [4].

Software-defined Systems are emerging and promising technologies to meet the needs of current IoT requirements. Software-defined networks (SDN) provide a centralized control and global view of the whole managed network by decoupling the control functionality from the forwarding plane and program network service located above the control plane. The centralized management allows efficient and automated optimization as well as configuration of the managed network [5].

Software-Defined Networks

In legacy networks the control and data plane are bundled inside the networking device, which reduces flexibility because devices need to be individually configured and control functions are often hard-coded. Thus, impeding innovation and evolution of the network infrastructure. Any changes to the network infrastructure are extremely expensive in terms of cost and time.

The software-defined network paradigm is considered to be an alternative to overcome the existing architectural challenges by decoupling the control plane from the forwarding plane in a three-layer architecture. However, the improved flexibility in network configuration and resource management that is provided by the higher level of abstraction can come at the cost of performance deterioration [6].

The three-layer architecture, as presented in [6], consists of a data or forwarding plane, a control plane and a management or application plane. The layers communicate with each other via open APIs called northbound interface and southbound interface:

- The data or forwarding plane consists of the actual physical devices, e.g., switches, routers and gateways. These forwarding devices act on the basis of instruction sets (policies) provided by the control plane on incoming flows or packets, e.g., forward, drop or manipulate a header.
- The southbound interface provides a communication protocol between the forwarding devices and the control plane, e.g., to distribute the instruction sets (rules) to the forwarding devices. One prominent communication protocol is OpenFlow [7].
- The control plane is the logically centralized part of the SDN and can be viewed as the brain of the network. The control plane manages the whole network and has a global view of the network. Examples for controller software are Open Daylight [8], ONOS [9] and Floodlight [10].
- The northbound interface represents a common interface for developing applications.
- The management or application plane consists of applications that leverage the functions offered by the northbound interface. Essentially, a management application defines the policies, that are eventually translated to southbound-specific instructions that program the behavior of the forwarding devices.

The separation of concerns introduced between the definition of network policies, their implementation in forwarding devices, and the forwarding of traffic is an important consequence of the SDN paradigm. This separation is the key property for the desired flexibility, breaking the network control problem into manageable pieces. Furthermore, it allows to easier create and introduce new abstractions in networking, simplifying network management and facilitating network evolution and innovation.

Software-Defined Storage

The immense increase in IoT devices inexorable results in huge amounts of data that is generated, transported, collected and analyzed. As a result of this development more and more storage systems are deployed. Virtualization techniques are used to utilize the underlying hardware to its fullest potential and support building manageable storage systems [12].

However, the complexity of a layered approach leads to the difficulty to enforce end-to-end Quality of Service policies, e.g., bandwidth, latency or priority requirements. These deficiencies make it necessary to establish a software-defined design of storage system, i.e., Software-Defined Storage (SDStore) system. The SDStore approach is based on the SDN paradigm and makes use of a logically centralized controller that has the ability to implement different policies on different kinds of flows [12].

Software-Defined Security

Traditional security mechanisms are not suitable for the SDSys architectures and therefore require new security mechanisms. Like all SDSys, Software-Defined Security (SDSec) provides a way to design, deploy and manage security mechanisms by separating the forwarding and processing plane from the security control plane. Thus, SDSec abstracts the security policies, e.g. intrusion detection, firewalling and others, from the hardware layer and run it in an independent software layer. The separation provides a scalable distributed security solution, which virtualizes the security functions but remains manageable as a single logical system, as [11] states.

4 Smart Cities and Smart Systems

The growing number of people living in a city poses a new set of technical challenges. This rapid progress, also referred to as urbanization, has led to many big cities producing continuous big data. The concept of a smart city was developed in order to handle all the information and to gain knowledge about a city that can help tackle the challenges.

For instance, the analysis of the city-wide human and vehicle mobility data helps to detect problems in a city's road network. This discovery can help better formulate city planning for the future [28]. Fig. 2 [19] presents a good overview over the connections and relationships in a city that can be used for developing smart systems.

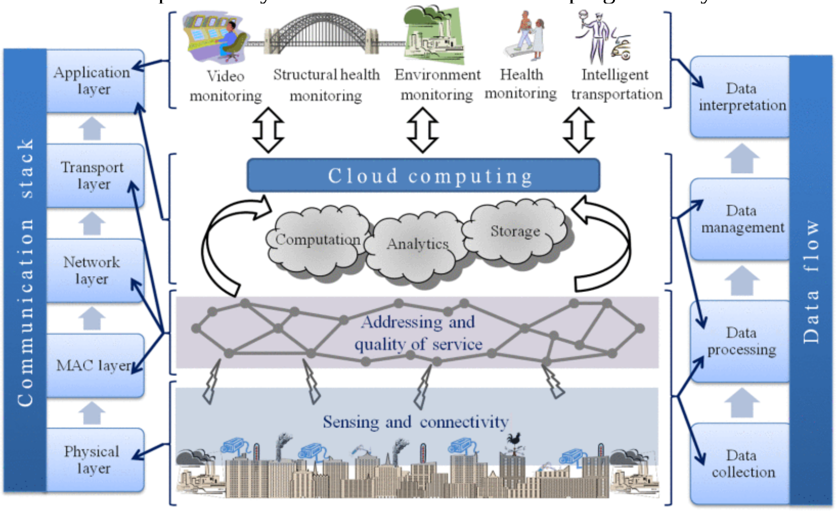

Fig. 2. IoT Infrastructure for Smart Cities [19].

Smart Mobility

Smart mobility is often described as visionary idea of transportation [26]. It should be applicable and usable for everyone regardless of location and region, usage period and duration and regardless of individual skills and budget.

However, in the context of smart cities, smart mobility involves not only transportation, such as autonomous vehicles, but also support for disabled or older persons as well as a real-time traffic control system.

Such a system, also referred to as intelligent transportation system (ITS), is the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency. It estimates the traffic parameter and optimizes traffic signal to reduce vehicle delays and stops by the uses of different techniques [27]. An ITS is part of the Internet of Things and includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology.

The data processing approaches in ITS rely often on Apache Kafka and Apache Spark's extension Spark Streaming we briefly presented in Section 2. The traffic management centers are responsible for data analysis that is mostly done with machine learning and deep learning applications.

Smart Health

To ongoing digitization has already transformed the healthcare system. The concept of electronic health (e-health) [22] was introduced and successfully integrated in healthcare. Meanwhile the concept of mobile health (m-health) [23] has arisen combining the characteristics of mobility and the benefits of e-health. In that way a treatment can be carried out and monitored at any time and in any place.

The development and increased use of IoT significantly transformed the health sector [24]. Intelligent devices communicate with each other over the internet, store and deliver vast amounts of data in the cloud for analysis and predictions. In the context of smart cities, the concept of smart health (s-health) was developed [25], which uses the existing infrastructure of the city for improvement of customized patient-oriented treatment. Smart city devices can also be used for real-time analysis and routing support of emergency services.

Smart Energy

By the transition of coal and nuclear energy towards renewable energy sources, new concepts for the long-term storage and efficient distribution of energy are essential. For example, in Germany [21] several model regions were developed for testing the new approaches regarding smart energy systems. Solar and wind energy as well as biomass and hydropower are the most important forms of renewables. Renewable energy becomes an important source of electricity worldwide. The key factors thereby are that the energy supply is to become more climate-friendly, and it will make countries less dependent on extraction and imports of fossil fuels.

Some of the examples of the new applications in this area are *smart grids* and *smart meters*. Smart grids represent an energy supply system that involves power generation, transmission, storage, distribution up to consumption of the electricity. The idea behind this concept is that each device which is connected to the electricity grid should be integrated on a "plug & play" basis. Smart meters are parts of a smart home and should replace conventional electricity meters. They will be integrated in the smart grids and should be able not only to measure the power consumption, but also to record voltage failures and to provide the grid operators with important information so that the power generation, grid loads and consumption can largely be adjusted automatically.

5 Conclusion

Digital transformation is increasingly becoming an overarching, everyday experience. It is changing the way people live, work and communicate with each other and with their surroundings. New possibilities, products and services are emerging. In order to maintain an active control of the digitization, it is necessary to monitor the changes in our environment and to adapt applied technologies making them smarter.

In this paper we presented an overview on changes and modifications of some selected concepts and technologies as an implication of the digital transformation progress. This work covers only a small part of the huge research and application area.

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