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A Framework of the Smart Environments and Integrated Ecosystems for Smart Cities with Big Data and Internet of Things

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Abstract: ***The Internet of Things (IoT) has been a major influence on the Big Data landscape. The main idea behind the IoT revolution is that almost every object or device will be having an IP address and will be connected to each other. Now, considering the fact that millions of devices will be connected and will be generating enormous volumes of data, the efficiency of data collection mechanism is going to be challenged. The Internet of Things (IoT) is on its way to becoming the next technological revolution. According to Gartner, revenue generated from IoT products and services will exceed $300 billion in 2020, and that probably is just the tip of the iceberg. Given the massive amount of revenue and data that the IoT will generate, its impact will be felt across the entire big data universe, forcing companies to upgrade current tools and processes, and technology to evolve to accommodate this additional data volume and take advantage of the insights all this new data undoubtedly will deliver for smart cities.***

Keywords: Internet of Things (IoT), Big Data**.**

1. Introduction

Advances in technology are quickly paving the way for smart cities. A smart city is an urban center that harnesses technologies, such as IT, to improve the quality of life of residents, manage available resources such as roads and water in economically sustainable manner, and reduce environmental pollution. According to figures published by the New Jersey Institute of Technology (NJIT), smart city technologies will grow to an industry worth $27.5 billion by 2023. In addition, the world will be home to about 88 smart cities by 2025[1-3].

Although most cities in developed countries function well, changes in population distribution patterns will make provision of services, accommodation, and transport a nightmare. This is largely because of population increase estimated to reach eight billion by 2025. Out of these, two billion will be seniors living longer due to advances in medicine and better healthcare. Currently, the world is home to 841 million seniors. People around the world are gradually moving from rural areas to work and live in cities. For instance, 82.3% of Americans today live in urban centers. As the number of commuters increases across major US cities, public transport systems will start to buckle. By 2030, the number of peak commuters in New York, Chicago, and Los Angeles will account for 29%, 28%, and 27% of all commuters using public transport systems [4-6]. Another major challenge is diminishing freshwater resources. Currently, a staggering 89% of global population relies on improved water supply systems that lose about 32 billion cubic meters of precious water via physical leakage. As a result, up to 50% of the world's population (four billion) will reside in water stressed areas by 2025. A growing global population will increase energy demand by 56% by 2040. In this category, the US holds the unenviable position of second highest energy consumer worldwide [7-9].

We might be surprised to learn how many things are connected to the Internet, and how much economic benefit we can derive from analyzing the resulting data streams. Here are some examples of the impact the IoT has on industries [10-12]:

- Intelligent transport solutions speed up traffic flows, reduce fuel consumption, prioritize vehicle repair schedules and save lives.
- Smart electric grids more efficiently connect renewable resources, improve system reliability and charge customers based on smaller usage increments.
- Machine monitoring sensors diagnose – and predict – pending maintenance issues, near-term part stock outs, and even prioritize maintenance crew schedules for repair equipment and regional needs.
- Data-driven systems are being built into the infrastructure of "smart cities," making it easier for municipalities to run waste management, law enforcement and other programs more efficiently.
- But also consider the IoT on a more personal level. Connected devices are making their way from business and industry to the mass market. Consider these possibilities:

For example, you're low on milk. When you're on your way home from work, you get an alert from your refrigerator reminding you to stop by the store. Your home security system, which already enables you to remotely control your locks and thermostats, can cool down your home and open your windows, based on your preferences [13-15].

Data Storage: When we talk about IoT, one of the first things that come to mind is a huge, continuous stream of data hitting companies' data storage. Data centers must be equipped to handle this additional load of heterogeneous data. In response to this direct impact on big data storage infrastructure, many organizations are moving toward the Platform as a Service (PaaS) model instead of keeping their own storage infrastructure, which would require continuous expansion to handle the load of big data. PaaS is a cloud-based, managed solution that provides scalability, flexibility,

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compliance, and a sophisticated architecture to store valuable IoT data [16-18].

Cloud storage options include private, public, and hybrid models. If companies have sensitive data or data that is subject to regulatory compliance requirements that require heightened security, a private cloud model might be the best fit. Otherwise, a public or hybrid model can be chosen as storage for IoT data [19-21].

What is Different in IoT Regarding Big Data?

- Big data is characterized by having a particular challenge in one or more of the 3 Vs: Volume, Velocity and Variety.
- IoT presents challenges in combinations of them.
- Most challenging IoT applications impact both Velocity & Volume and sometimes also Variety.

Big Data Technologies: When selecting the technology stack for big data processing, the tremendous influx of data that the IoT will deliver must be kept in mind. Organizations will have to adapt technologies to map with IoT data. Network, disk, and compute power all will be impacted and should be planned to take care of this new type of data. From a technology perspective, the most important thing is to receive events from IoT-connected devices. The devices can be connected to the network using Wi-Fi, Bluetooth, or another technology, but must be able to send messages to a broker using some well-defined protocol. One of the most popular and widely used protocols is Message Queue Telemetry Transport (MQTT). Mosquito is a popular open-source MQTT broker [22-24].

Once the data is received, the next consideration is the technology platform to store the IoT data. Many companies use Hadoop and Hive to store big data. But for IoT data, NoSQL document databases like Apache Couch DB are more suitable because they offer high throughput and very low latency. These types of databases are schema-less, which supports the flexibility to add new event types easily. Other popular IoT tools are Apache Kafka for intermediate message brokering and Apache Storm for real-time stream processing [25-27].

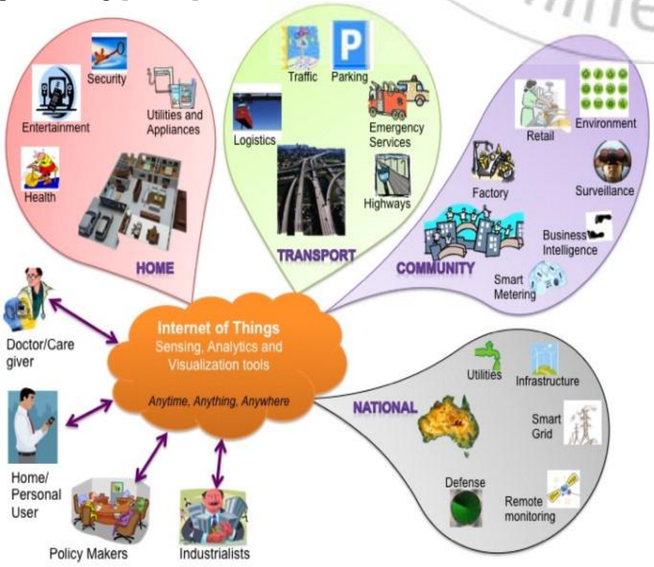

Figure 1: Internet of Things schematic showing the end users and application areas based on data

IoT Big Data Requirements [28-30]:

- How IoT applications are characterized with respect data needs?
- Let us look at different large families of applications: Smart-*
  a) Smart-City.
  b) Smart-Grid.
  c) Smart-Transport.
- Connected Things:
  a) Real-time monitoring of what "things" are doing, their operating conditions, their issues, their load, their configuration, etc.
  b) Predictive maintenance: fix before "things" break.
  c) Optimization: configuration, interaction with humans, energy efficiency, most suitable "things" for different uses.
  d) Analytics to find out the current shortcomings to design next versions of things.

IoT & Big Data [31-33]

- One of the most prominent features of IoT is its real-time or near real-time communication of information about the "connected things".
- For challenging IoT applications, the difficulty lies in doing this at scale (e.g. from 10s of thousands to 10s of millions and above).
- Smart-* scenarios are in many cases also characterized due to the Variety of data sources and data to be stored and processed.
- Another important feature of the vision of IoT is that by observing the behavior of "many things" it will be possible to gain important insights, optimize processes, etc.
- This vision boils down to solve multiple challenges:
  a) To store all the events (Velocity & Volume Challenge);
  b) To run analytical queries over the stored events; (Velocity & Volume Challenge)
  c) To perform analytics (data mining and machine learning) over the data to gain insights Velocity & Volume & Variety Challenge);
- Another angle in the vision of IoT is the ability of performing Real-Time Analytics.
  a) How to detect and react in real-time to opportunities and threats to my business;
- This requirement presents multiple challenges:
  a) How to process streaming events on the fly (Velocity challenge).
  b) How to store streaming events in the operational database (Velocity challenge).
  c) How to correlate streaming events with my stored data in the operational database (Velocity & Volume challenge).

Data Security: The types of devices that make up the IoT and the data they generate will vary in nature – raw devices, varied types of data, and communication protocol – and this carries inherent data security risks. This heterogeneous IoT world is new to security professionals, and that lack of experience increases security risks. Any attack could threaten more than just the data – it also could damage the connected devices themselves [34-36]. IoT data will require organizations to make some fundamental changes to their

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security landscape. As the IoT evolves, an unmanaged number of IoT devices will be connected to the network. These devices will be of different shapes and sizes and located outside the network, capable of communicating with corporate applications. Therefore, each device should have a non-reputable identification for authentication purposes. Enterprises should be able to get all the details about these connected devices and store them for audit purposes. All internal and external core routers/switches should be instrumented with X.509 certificates for creating trusted connectivity between public and private networks [37-39].

A multi-layered security system and proper network segmentation will help prevent attacks and keep them from spreading to other parts of the network. A properly configured IoT system should follow fine-grained network access control policies to check which IoT devices are allowed to connect. Software-defined networking (SDN) technologies, in combination with network identity and access policies, should be used to create dynamic network segmentation. SDN-based network segmentation also should be used for point-to-point and point-to-multipoint encryption based on some SDN/PKI amalgamation [40-42].

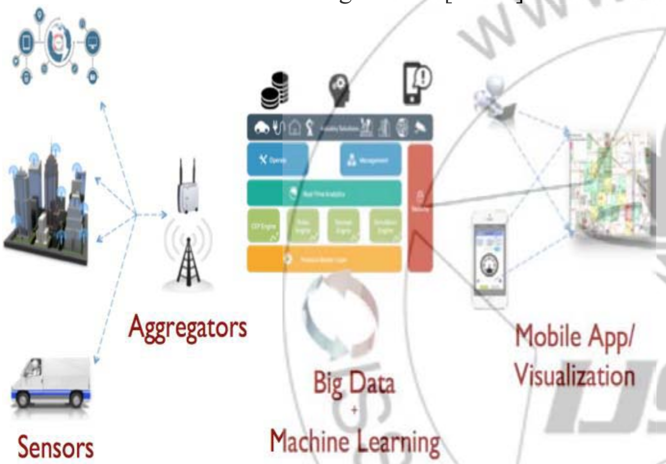

Figure 2: Smart City with Big Data and IoT

Big Data Analytics: IoT and big data basically are two sides of the same coin. Managing and extracting value from IoT data is the biggest challenge that companies face. Organizations should set up a proper analytics platform/infrastructure to analyze the IoT data. And they should remember that not all IoT data is important [43-45]. A proper analytics platform should be based on three parameters: performance, right-size infrastructure, and future growth. For performance, a bare-metal server, a single-tenant physical server dedicated to a single customer, is the best fit. For infrastructure and future growth, hybrid is the best approach. Hybrid deployments, which consist of cloud, managed hosting, colocation, and dedicated hosting, combine the best features from multiple platforms into a single optimal environment. Managed Service Providers (MSPs) are also working on their platforms to handle IoT data. MSP vendors are typically working on the infrastructure, performance, and tools side to cover the entire IoT domain [46-48]. An IoT device generates continuous streams of data in a scalable way, and companies must handle the high volume of stream data and perform actions on that data. The actions can be event correlation, metric calculation, statistics preparation, and analytics. In a normal big data scenario, the data is not always stream data, and the actions are different. Building an analytics solution to manage the scale of IoT data should be done with these differences in mind.

The growth of the IoT heralds a new age of technology, and organizations that wish to participate in this new era will have to change the way they do things to accommodate new data types and data sources. And these changes likely are just the beginning. As the IoT grows and businesses grow with IoT, they will have many more challenges to solve [49-51].

2. Motivation of the Research

Every minute, we send 204 million emails, generate 1.8 million Facebook likes, send 278 thousand tweets, and upload 200 thousand photos to Facebook. Is this statement about big data or the Internet of Things?

12 million RFID tags (used to capture data and track movement of objects in the physical world) were sold in 2011. By 2021, it's estimated this number will increase to 209 billion as [big data or the Internet of Things?] takes off. The boom of [big data or the Internet of Things?] will mean that the amount of devices that connect to the internet will rise from about 13 billion today to 50 billion by 2020. The big data or the Internet of Things? industry is expected to grow from US$10.2 billion in 2013 to about US$54.3 billion by 2017 [52-54].

The Internet of Things is the concept of everyday objects – from industrial machines to wearable devices – using built-in sensors to gather data and take action on that data across a network. So it's a building that uses sensors to automatically adjust heating and lighting or production equipment alerting maintenance personnel to an impending failure. Simply put, the Internet of Things is the future of technology that can make our lives more efficient [55-57].

- Implement privacy by design.
- Be transparent about what data is collected, how data is processed, for what purposes data will be used, and whether data will be distributed to third parties.
- Define the purpose of collection at the time of collection and, at all times, limit use of the data to the defined purpose and Obtain consent.
- Collect and store only the amount of data necessary for the intended lawful purpose.
- Allow individuals access to data maintained about them, information on the source of the data, key inputs into their profile, and any algorithms used to develop their profile.
- Allow individuals to correct and control their information.
- Conduct a privacy impact assessment.
- Consider data anonymization.
- Limit and carefully control access to personal data.
- Conduct regular reviews to verify if results from profiling are "responsible, fair and ethical and compatible with and proportionate to the purpose for which the profiles are being used."
- Allow for manual assessments of any algorithmic profiling outcomes with "significant effects to individuals.

As you can see, these documents do not express any new sentiments around data protection and privacy, but the fact

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that these issues could be articulated and adopted by these international data protection regulators show how important these issues have become in this big data-IoT era. Unfortunately, these documents are not binding, but they do provide relevant indicators on the direction data privacy policies and trends are going [58-60].

3. Research Problem

There is clearly a relationship between big data and IoT. The IoT Research helps confirm that. In fact, I would propose that big data is a subset of the IoT Research. Here's my rationale [61-66]:

- Big data is about data, plain and simple. Yes, you can add all sorts of adjectives when talking about "big" data, but at the end of the day, its all data.
- IoT is about data, devices, and connectivity. Data – big and small – is front and center in the IoT world of connected devices.
- Self-determination is an inalienable right for all human beings.
- Data obtained from connected devices is "high in quantity, quality and sensitivity" and, as such, "should be regarded and treated as personal data."
- Those offering connected devices "should be clear about what data they collect, for what purposes and how long this data is retained."
- Privacy by design should become a key selling point of innovative technologies.
- Data should be processed locally, on the connected device itself. Where it is not possible to process data locally, companies should ensure end-to-end encryption.
- Data protection and privacy authorities should seek appropriate enforcement action when the law has been breached.
- All actors in the internet of things ecosystem "should engage in a strong, active and constructive debate" on the implications of the internet of things and the choices to be made.

4. Research Objective

The challenges discussed above can be addressed effectively and efficiently through smart city technology. Nevertheless, this approach requires a multi-pronged approach because the problems are diverse. To start with, data scientists will have to use their skills to analyze the huge amounts of data generated by cities annually. Big data analytics will produce insights that city authorities could use to improve road and rail transport, reduce crime, improve healthcare, improve public service delivery, and reduce wastage of financial resources [67-69].

Another technology that will make smart cities more efficient is the Internet of Things (IoT). This computing term refers to appliances and devices connected to the Internet. Many household appliances including fridges, washing machines, vacuum cleaners, locks, lights, and HVAC units can be tweaked to become IoT compliant. In turn, they could be used to monitor and provide surrounding environment feedback or perform certain tasks.

In addition, cities can deploy this technology to improve service delivery. A good example would be water supply systems fitted with IoT sensors to measure water pressure, chemical composition, and flow. When undesirable changes occur, relevant authorities can take corrective measures immediately aided by real-time data.

Urban centers can also benefit greatly by installing and using energy-efficient IoT systems. The US alone would realize savings worth $1.2 trillion if it could deploy big data analysis for this purpose. Since urban transport systems are prone to bottlenecks such as traffic jams, technology would come in handy to improve efficiency. This would require GPS systems, cameras, and traffic light coordination systems connected via IoT to keep traffic moving.

Players in the food production sector would also benefit from technologies such as IoT and big data. Some farmers in the US use machinery that rely on data analysis and GPS guidance systems to manage fertilizer application, watering, weeding, and harvesting.

Several cities across the world have been quick to roll out smart city technologies. The City of Dubuque, IA has helped households realize water consumption savings of about 7% thanks to a smart water system running since 2010. In Spain, the city of Santander has cut energy and waste management costs by 25% and 20% respectively aided by 12,500 IEEE, GPRS, and RFID sensors installed throughout the city. Seattle has already initiated a High-Performance program to cut energy consumption via analysis of real-time data. San Francisco is on course to launch the I-80 Smart Corridor project featuring a network of cameras, sensors, and high-tech road signs. Smart city with Big Data and IoT Overarching research objective:

1) What does really matter for IoT application developers?
2) Having a platform to develop IoT applications as easy and fast as possible.
3) What it means for Big Data?
4) How to deliver platforms able to:
   - Correlate streams of data with stored data (Scalable CEP over scalable SQL/NoSQL).
   - Update operational databases with streams of data (Scalable CEP and scalable OLTP).
   - Perform analytical queries over operational databases (Scalable OLAP+OLTP).
   - Support the Variety in different data models and querying each data (queries and updates over polyglot persistent data).

5. Methodology

Sensors and distributed devices quickly create large volumes of data in IoT applications. Big data analytics refers to collecting, aggregating, and analyzing those large sets of data by backend systems before IoT applications can use it. Generating business value out of such data will be a key challenge for companies that offer new services to business customers and end users in the connected world.

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The Big Data Processing (BDP) component in the IoT Suite allows data analysts to analyze and evaluate the large data volumes generated in IoT applications. Graphical modeling in the component's workbench allows users to access and transform data, and also to generate powerful forecasts and visualize them for domain experts in highly relevant, informative displays. Our IoT platform allows users to analyze sensors and devices as well as customer master data and process data. Recognizing patterns and correlations within these huge masses of data and adapting services accordingly is an important prerequisite for successful IoT applications.

- First, companies need to employ highly efficient data collection mechanisms.
- Second, companies are going to face unprecedented security issues which are probably not going to be addressed with traditional security mechanisms.
- Third, not all data generated by the devices will be useful. Companies need to distinguish between useful and redundant data. So, they face huge challenges to improve their data and analysis capabilities. In this context, tools like Hadoop are going to receive a lot of attention.
- Last, IoT Big Data is going to change our day-to-day lives at a fundamental level.

Below we examine areas of Big Data landscape impacted by the IoT into smart cities with different area of expertise.

Figure 3: Vehicles in Smart City with Big Data & IoT

Collection of IoT Big Data: Companies need to collect all the data that is relevant to their business and that is a seriously challenging task because they need to filter out redundant data and also protect the data from getting attacked. This requires highly efficient mechanism that includes software and protocols. The most common data collection tool is the sensor-fitted devices. IoT data collection also requires custom protocols. Message Queue Telemetry Transport (MQTT) and Data Distribution Service (DDS) are two of the most comprehensive protocols. Both protocols can help thousands of sensor-fitted devices connect with real-time machine-to-machine networks. MQTT collects data from multiple devices and puts the data through the IT infrastructure. On the other hand, DDS distributes data across devices.

Generally, devices collect and transmit data over the network to a central server. For example, one of the largest shipping companies in the world, UPS, uses sensors in its vehicles to improve delivery performance and cut costs. The sensors monitor miles per gallon, mileage, number of stops, speed, and engine health and capture more than 200 data points every day for each of its vehicles. The data helps UPS to reduce fuel consumption, harmful emissions and idling time. Virgin Atlantic has been using IoT on its Boeing 787 aircrafts. According to David Bulman, the Virgin Atlantic IT Director, the data collected can help in improving flight performance and fuel efficiency and predicting maintenance requirements. Data Security Issues: The IoT has thrown new security challenges that cannot be addressed by traditional security mechanisms. Facing IoT security issues require a paradigm shift. For example, how do you deal with a situation when the refrigerator and coffee maker at your home are fitted with hidden Wi-Fi access and spambots?

Figure 4: Factories in Smart City with Big Data and IoT

In a trendsetting move, researchers have hacked the building control system of Google's office in Australia. According to experts, security issues have two aspects: hacking and confidentiality. For example, confidential data such as credit card details could be hacked with sophisticated methods and the owner would not even know.

Figure 5: Power Grids in Smart City with Big Data and IoT

Confidentiality means enterprises and even the government snooping about people's private lives to collect information in an unauthorized manner. IoT offers hackers and other cyber criminals a veritable gold mine of data. It has opened up new windows of accessing confidential data which were not available before. With just about everything in our lives about to get connected, data is going to flow out from everywhere. However, data security mechanisms have not been keeping pace with these developments. So cyber

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criminals have an unfettered entry. Privacy and confidentiality are going to take a hit because of companies callously handling customer data and the governments in many countries collecting information about our private lives on the sly. The images below show how confidentiality compromise is going to impact our lives in different areas.

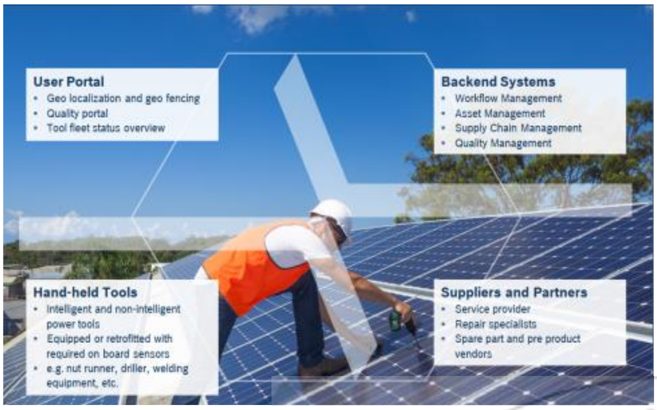

Figure 6: Supply Chain Management in Smart City with Big Data and IoT

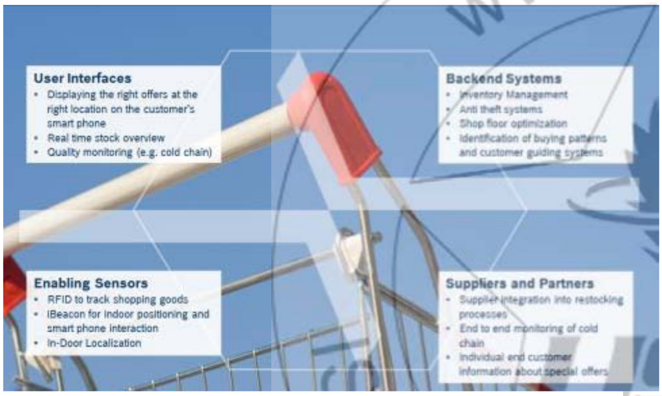

Figure 7: Super Market in Smart City with Big Data and IoT

Identifying Redundant Data

Not all of the Big Data from devices provide useful insights. At any time, companies are going to pull redundant data from the sources and it is not easy at the moment to filter out such data. A survey conducted by Par Stream shows that 96% of the organizations surveyed are struggling to filter out redundant Big Data from the devices. The following points emerged from the survey: More than 86% of the respondents recognize that efficient data collection is beneficial for their business. Few of the respondents are able to collect data efficiently and they realize that. The image below highlights the challenges organizations face with data collection efficiency.

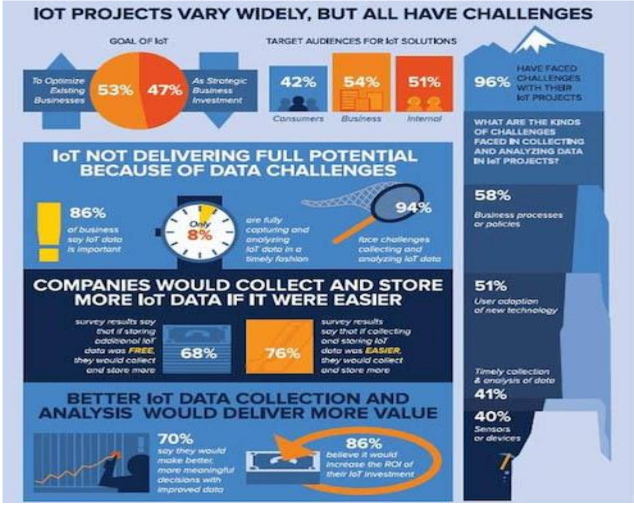

Figure 8: Smart Cities Data Collection with Big Data & IoT

It appears that data collection mechanisms are still at a nascent stage and so, teething problems are expected. The main reasons companies have not been able to employ better data collection methods are:

33% of the respondents do not track their IoT projects with quantifiable metrics. 29% of the respondents have documented goals for their IoT projects but do not measure the progress. The statistics below show the various difficulties companies are facing with data collection activities. The percentage figure indicates the percentage of the respondents to the ParStream survey facing the difficulty.

- Data collection difficulties – 36%
- Data is not captured reliably – 25%
- Slowness of data capture – 19%
- Too much data to analyze correctly – 44%
- Data analyzing and processing capabilities are not mature enough – 50%
- Existing business processes are not flexible to allow efficient collection – 24%
- Impact on Daily Lives

IoT Big Data is going to redefine our lives. Our lives are not going to be the same again. To keep things simple, let us consider a few examples of just three areas of our lives: work, home and health. At work, your keyboard or mouse could be fitted with sensors to find out how much time you spend at your desk. The coffee vending machine could measure from your ID card how much time you are spending in front of the vending machine. Obviously, your employer would want this information to find out how productive you are. At home, smart devices could save a lot of power and money by automatically switching off electrical devices when you leave home. You do not need to remember to switch them off. The music system in your car could automatically play just your favorite songs based on the data of your preferences. IoT will also help you handle medical emergencies efficiently and quickly. If someone at home is seriously ill, a smart watch or even a pacemaker could identify an emergency situation by analyzing the data such as heart beat, and blood pressure real time and send an emergency notification to the server of the nearest clinic.

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Expected Contribution

Our world is changing fast. People are sharing cars, generating their own energy for their homes, and finding ways to make machines communicate with each other. Key areas of our personal and professional lives are becoming increasingly interconnected. And that makes things easier – both at home and at work with possible contribution:

- Provides standard ETL (extract, transform, load) functionality in addition to powerful analysis and evaluation functions
- Facilitates cooperation between domain experts, data analysts, and IT specialists
- Provides the ability to create rich and interactive visualizations
- Integrates smoothly into the IoT Suite without disruptions between individual components in the suite
- Able to integrate external data sources
- Ensures the right data access rights are in place during evaluations using the IoT Suite's Identity Management component

6. Conclusion

Smart technologies generally have enormous benefits. For example, major cities that install smart transport systems will realize savings of about $800 billion annually from 2030 onwards. In addition, smart technologies will make it easier for emergency responders, firefighters, law enforcement officers, and traffic control workers to offer better services. IoT is definitely an exciting prospect from the Big Data perspective but we need to quickly improve our whole setup to handle the impact of IoT on the Big Data landscape. There are a few areas of concern and security and privacy and data collection efficiency are probably the most pressing problems we are facing. Security compromise and inefficiencies in data collection mechanisms result in a loss of reputation, time, effort and money. But there is hope because both the IoT and the infrastructure to manage it are at a nascent stage and there will be improvements

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