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White Paper

Getting More out of the Internet of Things with Real-time Analytics

About the Author

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Abstract

The Internet of Things (IoT) is changing the way people and businesses use devices. Billions of devices are already connected; as more continue to be added, businesses need to be ready to handle large quantities of data. This data can be a valuable resource to generate real-time insights into the performance of devices, as well as that of enterprises. Adding real-time analytics to the mix can enable organizations to reduce dependence on human intervention for monitoring performance.

This paper highlights how real-time analytics in IoT systems can be instrumental in optimizing these systems, while creating greater value for individuals and businesses through a range of user-friendly functionality. It also discusses some of the key technical components that an ideal IoT system should include.

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Deriving Value from Data Generated by the IoT

The growth and pervasiveness of the Internet of Things (IoT) have created a wide range of new data sources and data types that are vital to decision-making. The ability to gather and harness the voluminous data will help organizations differentiate themselves. Even as real-time access to this information provides organizations with significant growth opportunities, the emerging nature of real-time analytics, the scale of data, and the relatively unexplored application space produce some unique challenges. Therefore, before adopting IoT technologies, it is necessary to consider technical capabilities and challenges involved in making the data actionable.

The Need for Real-Time Analytics in an IoT-Driven Environment

The IoT brings into play an extensive range of new devices, technologies, and connectivity scenarios. The insights derived from the combined view of actionable data can help identify bigger opportunities for businesses than those presented by the devices individually. This is a classic case of the whole being greater than the sum of its parts.

Consider a smart home system with a television and thermostat connected to it. By harnessing data from both devices simultaneously, users can optimize their surroundings. For example, when the television is on in the living room, the temperature in the living room is adjusted automatically. The system can be set up in an office too. Information such as the current level of occupancy and employees' work schedules, as well as data from devices can help optimize energy consumption.

A key benefit the IoT imparts is the ability to simplify as well as optimize users' experiences. And accomplishing this objective in real time adds even greater value to the user. A smart car is much more effective if it provides real-time updates about the route and other conditions of the road, traffic, and weather.

Another example where real-time analytics data comes into play is in the case of industrial equipment IoT systems. These systems continually monitor the status of all devices, and their functioning, and use predictive analytics to recommend what components to repair and when. They also suggest fixes and upgrades. IoT systems such as these not only improve effectiveness and reliability but also optimize cost efficiency over time.

Implementing real-time analytics in an IoT environment is challenging due to:

- The large number of IOT devices and volume of data generated
- The need for processing and analyzing data at low latencies
- The need for Specialized visualization and reporting
- Non-standardized stack techniques and solutions

To achieve tangible benefits from IoT implementations, organizations need to incorporate two important features into their solutions monitoring and analysis coupled with optimization and actionability.

Monitoring and Analysis

IoT devices range from small sensors scattered across a user's daily life to large scale business systems such as power grids. It is not only important to get a holistic, high-level overview of the state of the connected things, but also understand the functioning of each connected device. In the smart home use case we saw earlier, the overall power and data consumption of each device connected through the IoT network needs to be monitored. In the event of anomalies, such as a sudden spike in power consumption, close monitoring will help users understand the situation better.

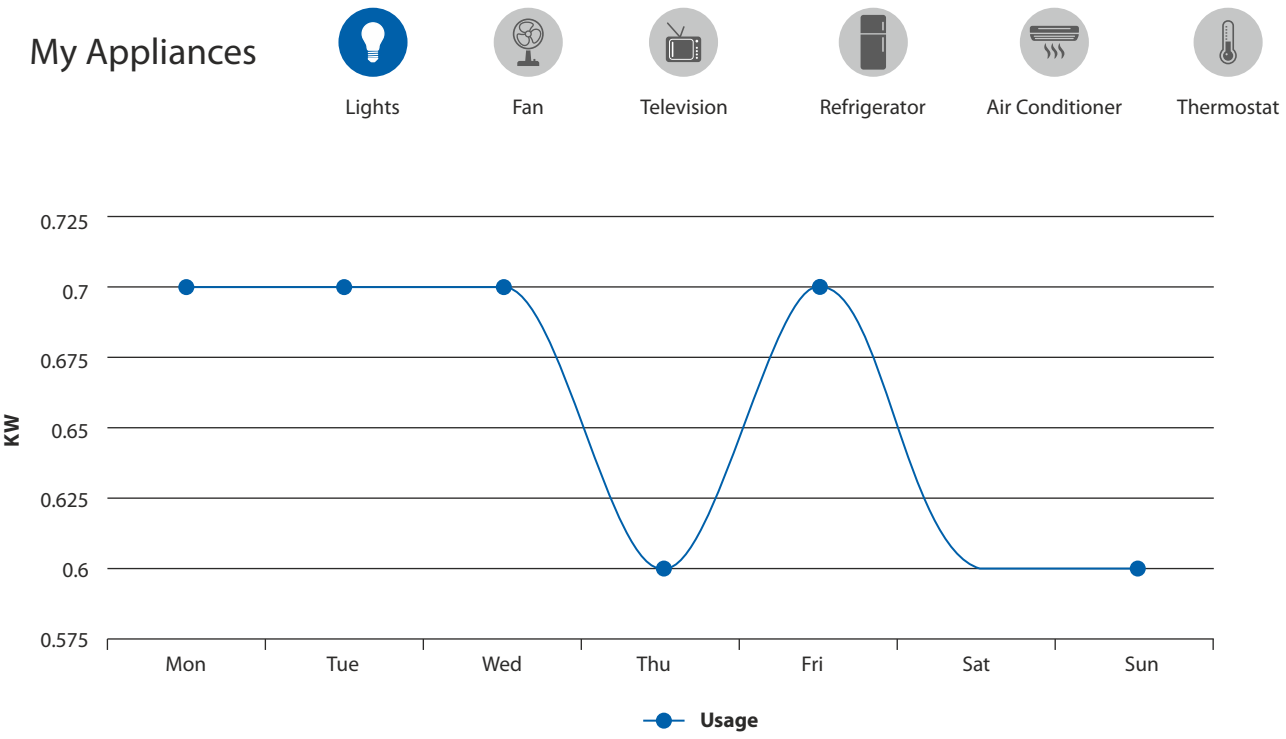

Figure 1: Dashboard showing daily power consumption of each appliance

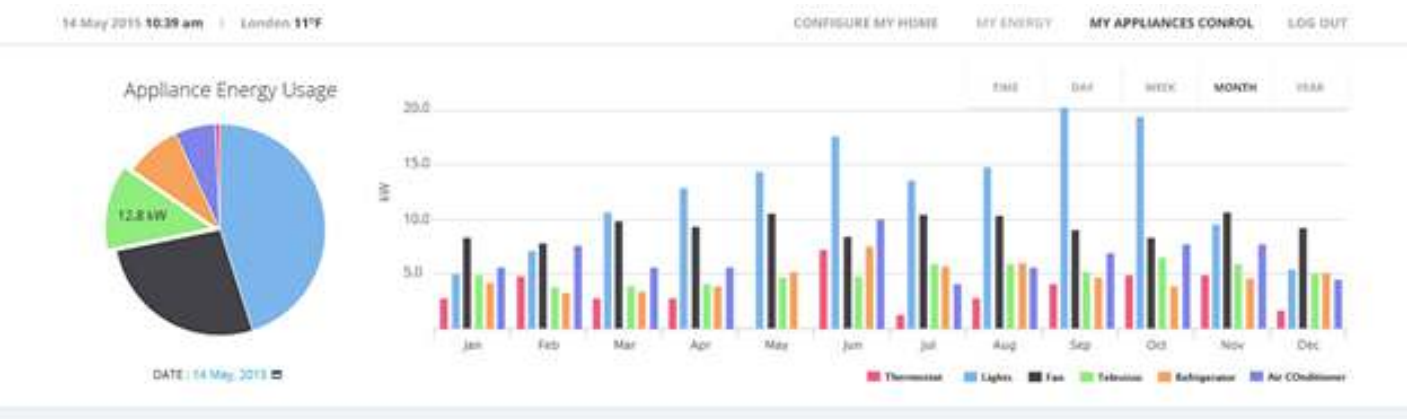

Figure 2: Dashboard displaying the monthly power consumption of multiple home appliances

Figure 2 illustrates the power consumption of various devices in a smart home by day, week, month, and year. This information helps optimize power consumption. On the other hand, Figure 3 indicates the power consumption by devices in each zone.

An IoT system therefore needs to offer real-time monitoring and diagnostics features to provide an overview of the current status, and enable the user to measure performance against historical data. Superior dashboard and visualization capabilities must be incorporated into the system to provide users a comprehensive overview of the IoT network. For businesses, dashboards should comprise summaries of high-level metrics and dimensions including power, data, connectivity, scheduling, overall system health, and industry-specific key performance indicators (KPIs). Each of these must be customizable and configurable to systems, and for different use cases. The ability to provide advanced visualization highlighting current trends can be a key differentiator for such a system.

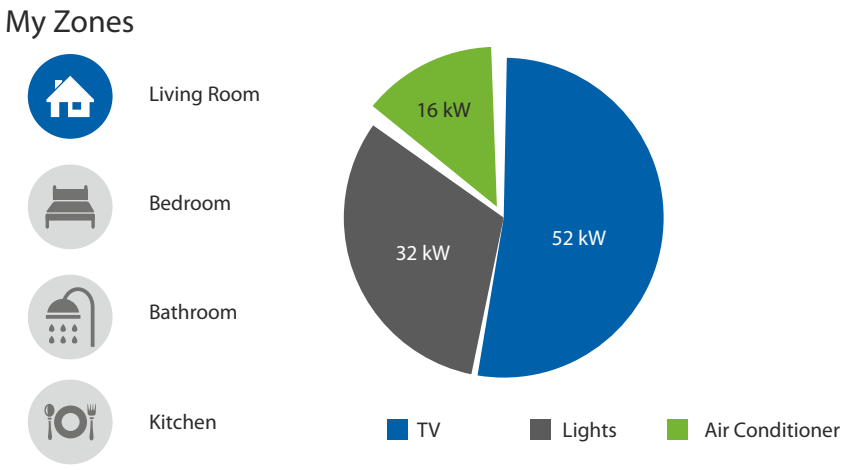

Figure 3: Dashboard displaying power consumption of devices in each room of a smart home

The example of the connected home highlights the need for the user to gain an overview of the data consumption of the entire house, as well as the ability to break it down by each individual component of the IoT system. The overview dashboard must provide enough information for the user to understand if the current energy usage is greater than what was consumed at an earlier point in the week, month, or year. This functionality must extend to every energy-consuming device in the house, and provide an individual analysis of each device. For example, the dashboard should take a zone-specific view, and should be able to highlight the fact that a smart television in one of the rooms is switched on and streaming a movie that no one is watching. The ability to both capture a high-level summary and seamlessly drill down to greater detail as needed should be the hallmark functionality of such a system.

Advanced analytics on data generated by IoT systems should help:

- Analyze data collected over a large period of time, and thereby gain a better insight into systems and their behavior
- Create models to forecast future outcomes or create control systems for optimization
- Collect information to estimate factors that would not be directly measured by sensors, by determining the relationship between different system parameters, and their impact on each other. For example, driving behavior is analyzed by measuring parameters of vehicle movement such as speed and acceleration.

Actionability and Optimization

Data is only as good as what one does with it, and real-time analytics for a user's IoT system is no different. The ability to look into what is happening within a system and its individual components allows the user to take necessary action if things are not going as well as expected. For instance, an app that allows users to remotely check whether their water system is running properly at home can offer peace of mind.

However, a real-time analytics system is much more than the ability to monitor the overall state of a user's connected world. The true vision of the IoT is about being able to use this data to automatically improve performance and functions on an ongoing basis. This would take the form of a control system that makes the desired changes by sending control signals to actuator endpoints. For example, a user can achieve energy efficiency by reducing the cold airflow in a heating, ventilating, and air-conditioning (HVAC) structure when the system detects that a particular space is unoccupied and it is not necessary to cool the area. The following sections illustrate a few use cases.

Automatic Monitoring and Alerting System

The examples cited earlier concern the user's ability to monitor an IoT system and detect anomalies as and when they happen. However, it may not be easy for the user to oversee a growing number of devices; this would likely defeat the IoT's vision of simplifying the user's life.

Ideally, the system must allow the user to set parameters to monitor devices automatically, and alert the user when things go awry. In the energy use case presented earlier, the system would enable the user to set a threshold for peak data usage over a period of time, and have the analytics system monitor and notify the user if data usage

exceeds the expected levels. This transforms the underlying system into a push-based system where the user's intervention is required only when things go beyond expected limits.

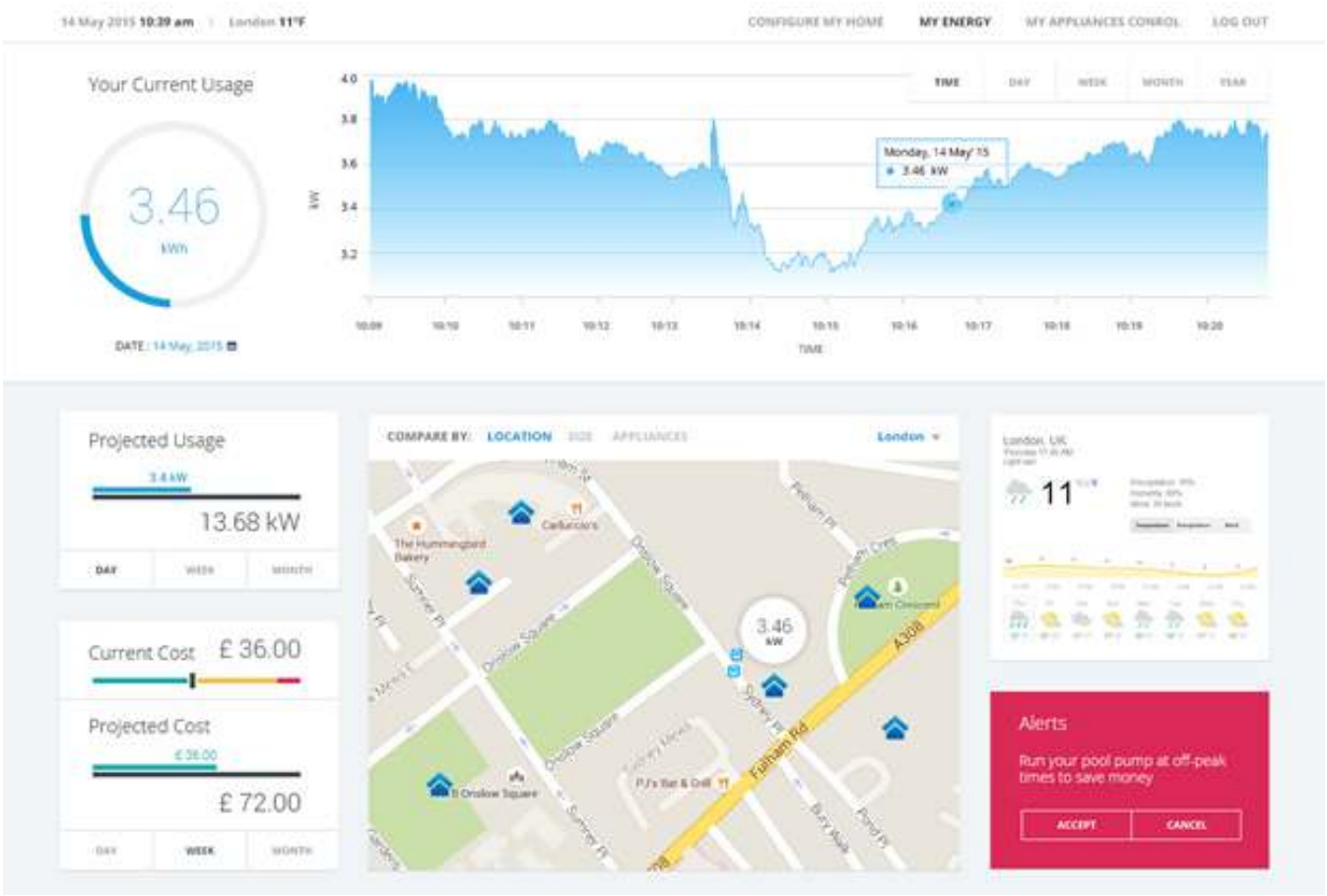

Figure 4: Real-time analytics dashboard of a user's home

For example, it would be useless, and even dangerous, for a user to only know that carbon monoxide (CO) levels in the house are high a few hours after it happens. The system should be able to notify the user as soon as something goes wrong. Therefore, real-time data is absolutely critical.

However, the system needs to go beyond merely alerting the user to take action in case of danger. The real-time analytics system must constantly monitor and learn on the user's behalf, adjust, and notify the user of changes as soon as they happen, and initiate the necessary corrective action automatically. For instance, in case the CO level at home crosses the safe threshold, the system can instantly inform the occupants and emergency services, shut down the gas pipelines, and automatically start the exhaust system. The dashboard in Figure 4 displays an alert to run the pool pump at off-peak hours to save energy and costs.

Optimization System

A central system that collects and analyzes data from the user's systems, and directs them to change behavior in real-time based on this data, would optimize the entire process. It enables the user to change roles from merely monitoring systems and setting thresholds to setting higher goals to optimize power management. For instance, sensors placed in a house can reveal that nobody is in the bedroom; the optimization system can gather this data in real time and use it to turn off the air-conditioning in the room or to adjust it to a higher temperature. Over a period of time, the system becomes smart enough to detect such patterns in energy usage and work towards further optimizing overall energy consumption.

Technologies for Next-Generation IoT Systems

An IoT system requires a strong underlying technical stack. A powerful platform that not only provides a functionality set, but also allows others to leverage and extend it further, can optimize the process. Here are some of the key technical components that such a system should include.

Data Collection API and Instrumentation System

In order to seamlessly collect data across a range of IoT devices, it is important to provide a simple, extensible, and easy-to-use collection application program interface (API) and protocols that will allow devices to send data easily to the back-end systems. Such an API should require minimal ramp-up to allow for quick usage in development but include scalability for advanced users to instrument at greater depth, if needed. The API should be extensible enough in definition, constructs, and wide-spread functionality to represent a varied range of devices.

A helpful library and software development kit (SDK) support makes it easier for developers to allow common platforms to use the API.

Data Collection Back-end and Stream Processing System

One of the key infrastructure components in such a system is a large-scale data collection and stream processing or complex event processing back-end that can collect data on billions of events in real time. Systems such as Apache Spark provide large scale and low latency stream processing. IoT solutions should support connectors to such systems, as well as provide their own infrastructure and components that can be easily deployed at a large scale, either in-house or server-side..

Reporting Back-end and Analytics System

Analytics back-end data warehouse and extract, transform, and load (ETL) systems have existed for some time now. For a large scale analytics system to be successful, it must be backed by powerful analytics at the back end. This could range from traditional Structured Query Language (SQL) engines to newer high throughput cloud query systems such as Amazon Redshift, Google BigQuery, and HP Vertica. Many companies also deploy their own Hadoop-backed SQL and/or NoSQL systems that allow a user to create cubes of data that can be efficiently queried in either a predetermined or an ad hoc manner. Advanced querying and analytics support enables predictive

analytics and data mining. This can then be applied to a wide range of problems and applications (such as forecasting, clustering, and time series modeling).

The schema and layout of these systems are critical for reporting, as both current and historical data are required to perform a comparison analysis. It is also important to run additional processing functions on this data for deeper and highly-customized investigations such as predictive analytics.

Rich Visualization and Dashboard Systems

IoT solutions should aim to provide a superior set of dashboard and visualization functions. A majority of users are likely to be passive high-level consumers of the data, and a user-friendly dashboard engine is critical to serve their need. Real-time analytics dashboards and reports are much more specialized than traditional visualization. This is because new techniques are used to represent the streaming and current nature of the data such as rapid updates in video-like user flows.

The system also needs to provide high quality visualization for advanced users to conduct deeper analysis.

External APIs and Connectors to Other Systems

The final, critical component of the system is the ability to take real-time data, and its analysis, from the core system and apply it directly to the user's business workflow. While IoT solutions offer superior reporting functionality, it is important to provide seamless data integration with the unique needs and workflows of individuals or businesses. Rich data APIs can facilitate transfer of the data from one system to where it is needed. This would also include easy connectors to other common platforms (such as mobile app software development kits) that allow developers to easily build higher layer applications on top of the data.

The Future of Real-Time Analytics in IoT Systems

Real-time analytics for IoT systems and platforms will become critical for businesses to differentiate themselves in the future. It will not only help reduce operational costs, increase productivity, and optimize the use of resources, but also uncover new service and business opportunities, including smart energy applications and solutions to build smart homes, offices, and cities. Given the large data generation possibilities of an IoT system, it is vital that the scale of data is processed and analyzed quickly to provide actionable intelligence through effective visualization and alerts.

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