RunMyProcess.

a Fujitsu company

Leveraging the Internet of Things:

Emerging Architectures for Digital Business

A radical new era of connectivity

Connectivity is the great disruptor. Whether it is the connectivity that containerization brought to physical supply chains or the connectivity that the Internet has brought to digital ones, the ability to reliably and scalably connect things literally transforms the way we think about the world. Connectivity allows us to build on what has been done before, to leverage shared expertise and resources and to integrate value in new ways to create hitherto unimaginable products and services precisely focused on the needs of our customers.

The Web itself has been a profound vehicle for increasing connectivity. It has been constantly growing outwards from its relatively simple beginnings as a platform for information sharing and linking. Over the last 20 years we have seen successive innovations – e.g. web sites, ecommerce, cloud computing, social networks and mobility – drive the influence of the Web into new areas, connecting new resources, digitizing new interactions and challenging the underlying beliefs on which a range of industrial and social activities were based. Every additional expansion has brought new industry leaders – e.g. Amazon, Google, Facebook or Uber – who have used greater connectivity to look at the world with fresh eyes, unencumbered by outdated beliefs and practices. A recent study suggested that the average tenure of companies in the S&P 500 index has dropped from 61 years in 1958 to just 18 years in 2011[1], something that appears to be moving in parallel with greater connectivity. For CIOs each successive expansion of connectivity brings new opportunities and challenges; the current disruptive convergence of cloud, mobile and social technologies is creating so great a demand for digital-fuelled change that many CIOs appear to be struggling to adapt.

While today's challenges are already acute, we are on the cusp of an almost unimaginable acceleration of connectivity and digitization. The Internet of Things (IoT) promises to drive the boundaries of the Internet further out than ever before, providing network connectivity to potentially billions of everyday objects. The sensors and actuators these objects embed will enable us to transform our understanding of real world events and to enact changes simultaneously across digital and physical spaces in real time. As IT increasingly merges with life itself, the distinctions between the physical and digital worlds will fade away, leaving technology as an embedded facilitator of everyday life.

The potential for reinvention that this merging creates is literally incredible. As connectivity transforms the potential of even the smallest and most mundane of everyday objects, huge new opportunities to orchestrate value flows across the digital and physical worlds will emerge. The importance of this cannot be overstated – despite today's huge wave of digital disruption, we are still effectively speaking about resources and activities whose fundamental nature can be converted from analogue to digital form – e.g. music, books, films, holiday pictures, status updates, insurance claims, shopping lists, airline bookings etc. The opportunity to transform and connect all of these newly digitized assets has indeed been – and continues to be – hugely disruptive, but they still only represent a tiny minority of the resources that exist in the real world.

The new wave of connectivity and digitization brought by the IoT will be different. In this case we are not talking about a conversion of information-based resources from analogue to digital form, but rather an ability to extend our digital awareness and control deeply into the realm of the analogue world. Such a shift brings disruptive change to the far greater number of activities that are yet to be touched by digitization, offering opportunities to overturn a much wider range of assumptions about the nature of people, places and things. Once again, as established assumptions break down in the face of increased connectivity, smart startups and wily challengers will have an open field to re-imagine entire industries.

But how do we become winners in this new environment? We believe that there are a number of historical perspectives that can help to guide us.

Lessons from History

The Internet is the platform

The first perspective suggests that we can only achieve the full potential of the IoT by stressing the "Internet" over the "Things". Despite many waves of technology hype over the years, straightforward connectivity has been the most fundamental driver of transformational change; connectivity allows activities to be broken down, shared and reconnected in new and often unforeseen ways. Technology optimization can happen later, once we are armed with evidence and an understanding of the necessary performance parameters. In this sense the most important consideration in creating a viable IoT strategy is not the optimization of wireless networks, the quality of sensors, the extensibility of boards or the choice of operating systems; rather the first and foremost consideration has to be maximizing the ease with which smart objects can be connected to the wider environment.

To this end, we believe that it is critical to base IoT initiatives on existing Internet and Web standards – or reasonable optimizations thereof – at different layers, leveraging the ubiquitous protocols and patterns of the Internet to maximize connectivity potential.

Think small to go large

The second perspective suggests that innovation on the Web has rarely been achieved in a top down, centrally planned fashion. Rather it has been an emergent property based on the connection of individual ideas, resources and value into larger solutions. It is the open, chaotic and Darwinian nature of the Web that has enabled such a high tempo of innovation, requiring people to conform to some simple standards but otherwise leaving them free to invent and connect anything they want. Many discussions of the IoT, however, start with huge, complex and monolithic predictions of smart energy, smart agriculture, smart manufacturing, etc., which are on a scale that has little relevance to most people and cannot be grasped in terms of the small, actionable changes that will get us started. Such initiatives are likely to be the preserve of governments and regulated industries that move slowly and have cash to burn.

In our view the more compelling scenarios are those that find specific, small scale and sustainable uses for sensors in improving or transforming a specific product, activity or process and then connect them together over time. We already see huge bottom up innovation happening as individuals and companies use sensors embedded within phones, fitness items or smart watches to connect unrelated devices and services to create higher levels of unforeseen value. As with the Web we believe that we will see a gradual layering of value as connectivity builds upwards from specific smart objects, into smarter processes and ultimately into large scale connected systems. In this sense we believe that successful approaches to IoT will need to leverage simple technologies and small scale approaches that lower the barrier to entry for each individual case.

Connect in the cloud

Finally the third perspective suggests that creating systems to orchestrate the end to end business flows that connect smart objects with other resources will be best achieved in the cloud. Connectivity of smart objects – while a great enabler to innovation – is only a partial answer. To create end to end solutions we must also connect these resources at scale – both with each other and with information systems and people. We believe that the highly distributed nature of the Web makes the use of cloud development and integration platforms a highly desirable option for digital process creation. The independent status of cloud platforms – as shared utilities not bound to any particular geography, usage domain or environment – makes them an ideal candidate for the orchestration and mediation of services and data from many distributed sources. Furthermore by acting as application-level intermediaries they can offer a host of useful operational, management and reporting capabilities that lower the burdens placed on low power systems at the edge of the network and increase the scale and responsiveness of the overall architecture.

Most importantly, by leveraging the opportunity to consolidate all of the necessary infrastructure, middleware and operational management within a cloud platform we can create a high productivity environment for the rapid creation and scaling of digital processes. The huge explosion in application innovation facilitated by cloud platforms over the last few years has amply demonstrated the power of reducing friction in the development process. We therefore believe that providing higher leverage tools for the rapid and reliable composition of smart objects at scale within the cloud can likewise accelerate experimentation, testing and adoption of IoT.

Building a Web of Everything

While there are already highly vertical sensor applications within specific domains (e.g. building automation, industrial M2M, logistics), they are implemented with a wide range of proprietary and incompatible technologies that are difficult to integrate with each other and with Internet-based services. This tightly constrains them to the use cases for which they were created, limiting their impact and blocking opportunities to reuse them within potentially valuable alternative scenarios. Extending these systems to the Web requires us to address three highly inter-related issues of scale: firstly scaling down the cost of connecting individual objects to the Internet, secondly using this reduced complexity to massively scale up the number of connected nodes and thirdly the need to connect information and services from this new ecosystem to the Web. To achieve these aims we need to consider two essential aspects – firstly the way in which we connect smart objects to the Internet and secondly the way in which these smart objects communicate with other Web-based resources.

Towards an Internet of Things

To reduce the costs of smart object connectivity the IoT aims to use IP to displace proprietary approaches at the networking level. Doing so promises to remove translation gateways, increase scalability, reuse network management approaches and accelerate innovation. To achieve this we need to overcome two major challenges; providing sufficient IP addresses and recognising the limited capabilities of many smart objects.

Scaling up Internet Protocol for the IoT

Achieving the full potential of the IoT requires a unique public IP address for each individual smart object – something that will lead to an explosion in the number of IP addresses required globally. Fortunately the Internet Protocol version 6 (IPv6) enables an almost unlimited number of addresses, putting in place the address space necessary to enable the use of IP as a low cost and scalable source of connectivity for smart objects. While uptake of IPv6 was initially slow, the demands of the IoT are starting to accelerate its deployment.

Scaling down Internet Protocol for small devices

Today a range of IP-enabled devices are already being successfully used as nodes within the IoT (e.g. Raspberry Pi), but these devices are the most powerful that fall within the IoT spectrum. To enable us to massively scale the number of connected objects we need to shrink them and minimize their cost. To achieve this the majority of devices will likely use cheap 8 or 16 bit microcontrollers and short range, low power wireless technology with limited data rates. Such constrained devices lack the powerful processors, operating systems and TCP/IP stacks required to use traditional IP.

To deal with these issues the IETF created 6LoWPAN, a wireless standard enabling IPv6 to be used within networks of constrained devices. 6LoWPAN deals with compression, data loss, power drain and device unreliability to enable the efficient extension of IPv6 into the domain of constrained objects. In doing so 6LoWPAN facilitates the end-to-end IP networking required to bring even the smallest and least powerful objects into the scope of the IoT.

Towards a Web of Things

While IPv6 and 6LoWPAN bring connectivity at the network level they do not deal with the need to create an open architecture at the application layer – a pre-requisite to achieving new digital ecosystems. One natural way to unify application-level communication is to reuse existing Web architectures and protocols such as REST/HTTP. While this approach simplifies the integration of smart objects with other Web-based resources it again only works well for high capability objects. The performance, memory and reliability profiles of many constrained devices mean that REST/HTTP is unlikely to be suitable for the whole range of devices that need to be connected.

To address these issues, the IETF has been focused on introducing the REST architectural style in a form suitable for constrained devices and networks. The resulting Constrained Application Protocol (CoAP) achieves this by implementing a subset of REST that is common with HTTP but optimized for constrained devices and networks – introducing UDP transport, reduced message overheads, reliable message delivery and an asynchronous interaction model. At the same time this approach drastically reduces the complexity of developing Web-based systems that consume smart object resources by establishing a consistent interaction model that is easily mapped to HTTP. Individual resources continue to be identified and addressed via Universal Resource Identifiers (URIs), are able to be represented using arbitrary formats (such as JSON or XML) and can be manipulated using the same methods as HTTP. Finally security and privacy concerns can be addressed using the familiar DTLS protocol using a range of authentication mechanisms. In this way the proposals deliver a sustainable basis for a new Web of Things, easing the challenges of creating IoT based applications while simultaneously paving the way for easy integration with broader Internet services.

A new Web of Everything

Together IPv6 and CoAP extend the Web into the realm of constrained devices and create a broader “Web of Everything”.

To leverage the full breadth of this new environment, however, we still need a way of connecting these new Web-based services at scale.

Connecting digital flows in the cloud

We believe that cloud platforms will ultimately consolidate all of the technical and business capabilities required for the rapid implementation of digital solutions spanning the whole spectrum of Web connected services – especially given the dependency of such solutions on high levels of adaptability, multi-tenancy, scalability and connectedness.

To facilitate the consistent integration and orchestration of different resource types within the RunMyProcess cloud we have introduced a number of important concepts:

- Connectors provide a uniform way to access distributed resources (whether using standard Internet protocols or not);
- Composite APIs offer aggregated REST interfaces that compose the outputs of one or more connectors;
- Business processes enable the creation of long running activities spanning any combination of human and system resources.

Given the rapid convergence towards Web-like protocols, IPv6 and CoAP provide the ideal basis to extend the reach of the RunMyProcess platform into the world of smart objects while preserving the ability to deliver end to end service composition.

Extending to the Internet of Things

To integrate smart objects alongside other Web-based services we offer connectors with native outbound and inbound CoAP support. These connectors are based on the open source Californium (Cf) framework.

For outbound support our CoAP connector manages the process of initiating and making calls to CoAP-based resources and of receiving and dispatching the asynchronous response to the invoking client. As with our other connectors, the CoAP connector is configured by specifying e.g. URL, options, content and result format within a cloud-based connection wizard.

For inbound support we have created a gateway that can receive CoAP calls, confirm receipt and then route them to the appropriate composite API service for processing.

Together this combination of outbound and inbound integration enables a wide range of digital composition, intermediation and enhancement use cases within the model already established for other Web-based services.

Benefits of connecting services in the cloud

Our experiences suggest that there are a number of additional potential advantages to integrating and orchestrating IoT resources from the cloud.

Simplification and Externalization of Function

Using the cloud to externalize application logic from individual smart objects where possible ensures they remain simple and focused on their main purpose. This increases the ease of maintenance and adaptability of IoT based applications by avoiding unnecessarily tight coupling between devices. The removal of overly constraining domain models also encourages new and unforeseen uses.

Composition and Abstraction

Simple resource composition can enable the creation of "virtual sensors," a collection of resources addressed as if they were a single entity (e.g. services that address all lights in a building or gauge mood from sensor data combined with Facebook updates). Such virtual sensors can abstract complexity without removing the flexibility to address individual objects when necessary.

Resource Management

Uncontrolled usage of constrained devices could quickly lead to performance degradation and/or power issues. Cloud platforms can protect resources from failure by adding throttling, caching or billing capabilities to shape usage behavior. Without such mediation resource owners and consumers need to individually manage interactions – a daunting and potentially impractical task.

Service Convergence

Enabling intermediation between smart objects and other Web-based resources helps to reduce integration barriers between the virtual and physical worlds and encourage the emergence of converged solutions. In this model digital applications and processes can be created in the cloud that seamlessly span the full range of Internet-connected resources.

Security Adaptation

From a security perspective an intermediate platform can be used to add security proxies to resources which are insufficiently powerful to process the additional overheads of DTLS communication.

Unified Discovery, Subscription and Monetization

As the IoT expands it will become more difficult to find and use appropriate devices. Cloud based application and API marketplaces that simplify the discovery and consumption of Web based services could make IoT resources easier to find, subscribe to and monetize.

Insight and Analytics

Monitoring and managing large networks of devices is set to be a daunting task, but the use of cloud platforms to intermediate and orchestrate devices could provide valuable insight into their performance and help identify issues. Over time the analysis of aggregated data could be used to make suggestions on service optimization or to predict failures.

Bringing It All Together – a Simple Example of Digital Flow

One very simple but illustrative example of the end to end connectivity made possible by the Web of Everything has been implemented as part of a thought-leading European project. In this solution a presence sensor in an office detects unauthorized persons out of hours. If triggered an alert is sent to a local control and monitoring system to sound an alarm and a CoAP message containing a phone number is sent to the RunMyProcess platform. On receiving the alert, RunMyProcess sends an SMS to the transmitted phone number and creates a new incident within an incident management system. The notified user can view the incident within a RunMyProcess provided mobile app and choose to investigate or deactivate the alert. When deactivation is chosen a CoAP message is sent from RunMyProcess back to the office building to cancel the alarm and the incident system is updated to close the case.

While simple in concept this application demonstrates a number of important aspects of the emerging IoT. Firstly it shows the viability of rapidly creating low cost and small scale systems that address a specific issue in isolation – in this case a sensor, an alarm system and a cloud application are used to protect a single office. Secondly it demonstrates the use of IPv6 and CoAP to facilitate connectivity between smart objects and other Web services, resulting in the straightforward creation of a business process spanning the IoT, the cloud and a human actor. Thirdly the speed and low cost with which such a process can be delivered makes a compelling argument for the use of cloud platforms for coordination. Finally the aggregation of information in the cloud provides a repository of data about patterns of intrusion.

Conclusion

In this whitepaper we have described the potential of the Internet of Things as an enabler for new digital business models. We have also outlined the key technologies that are moving us beyond network connectivity and facilitating a new era of Web-based application development that encompasses real world data and actions. Finally we have discussed the use of cloud platforms to leverage this convergence towards Web-based approaches and simplify the creation of end to end solutions based on the new Web of Everything. We believe that leveraging these elements together will enable rapid business model experimentation and innovation. We hope that such convergence will accelerate the spread of sensor usage by making it simple to flexibly connect IoT information streams both to each other and to other Web-connected systems.

The IoT is opening up huge new opportunities to integrate information spanning the physical and digital worlds. While grandiose concepts and highly technical language can make the subject seem overwhelming, simple examples like our office system demonstrate the viability of starting quickly at a small scale. In fact many hobbyists and hackers are already using open source software and hardware – such as Arduino – to connect and automate a huge range of activities at extremely low cost.

In our view the first key step is therefore to actually take a first step; the low cost of starting, immense potential for experimentation and importance of gaining insight into this disruptive new area all make it critical to start shaping your future now.

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