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A Practical Framework to Turn IoT Technology Into Operational Capability

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INTRODUCTION

There will be an estimated 34 billion devices connected by 2020[1], depending on which analyst or research organization is referenced. The exact number of connected devices may be uncertain, but the impact on individuals and businesses will be significant. McKinsey & Company[2] estimates that linking the physical and digital worlds could generate up to $11.1 trillion a year in economic value by 2025.

The real challenge for Industrial Internet of Things (IoT) is not technological, but rather about managing and integrating change in organizations that need to operate in new and different ways.

In this article we present a framework that focuses on leveraging IoT technology to deliver real business value and to manage the move from a technology perspective to a business outcomes perspective. It is presented as a practical collaboration tool with an example of a Fortune 10 Oil & Gas organization that realized savings of $8 million in 6 months using the IoT to Operational Capability (I2OC) framework described in this article.

MOTIVATION

A July 2017 survey by McKinsey & Company[3] uncovered a number of serious capability gaps that could limit the potential of IoT in the enterprise. Some of these relate to technical and data extraction capabilities, but 70% of respondents cited "integrating IoT solutions into existing business work flows" as a major capability challenge. "For instance, 70 percent of respondents stated that companies have not yet integrated IoT solutions into their existing business work flows – in other words, they are not using enterprise IoT to optimize day-to-day tasks".

As technology advances and economies of scale bring sensor prices down, many of the initial engineering issues around IoT are solved. Organizations that started their IoT journey with Proof of Concept (PoC) projects demonstrated it is possible to connect their machines and sensors to the internet and extract data from it. But this is just the tip of the iceberg in creating new operational capabilities that leverage IoT technology at enterprise scale. A survey conducted by Cisco[4] in May 2017 with 1845 IoT decision makers shows that 60 percent of IoT initiatives stall at the PoC stage. Furthermore, only 26 percent of companies have had an IoT initiative that they considered a complete success. It is one thing to demonstrate 5 pumps in a

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[1] http://www.businessinsider.com/bi-intelligence-34-billion-connected-devices-2020-2015-11/

[2] http://aegex.com/images/uploads/white_papers/Unlocking_the_potential_of_the_Internet_of_Things___McKinsey__Company.pdf

[3] https://www.mckinsey.com/global-themes/internet-of-things/our-insights/taking-the-pulse-of-enterprise-iot

[4] https://newsroom.cisco.com/press-release-content?articleId=1847422

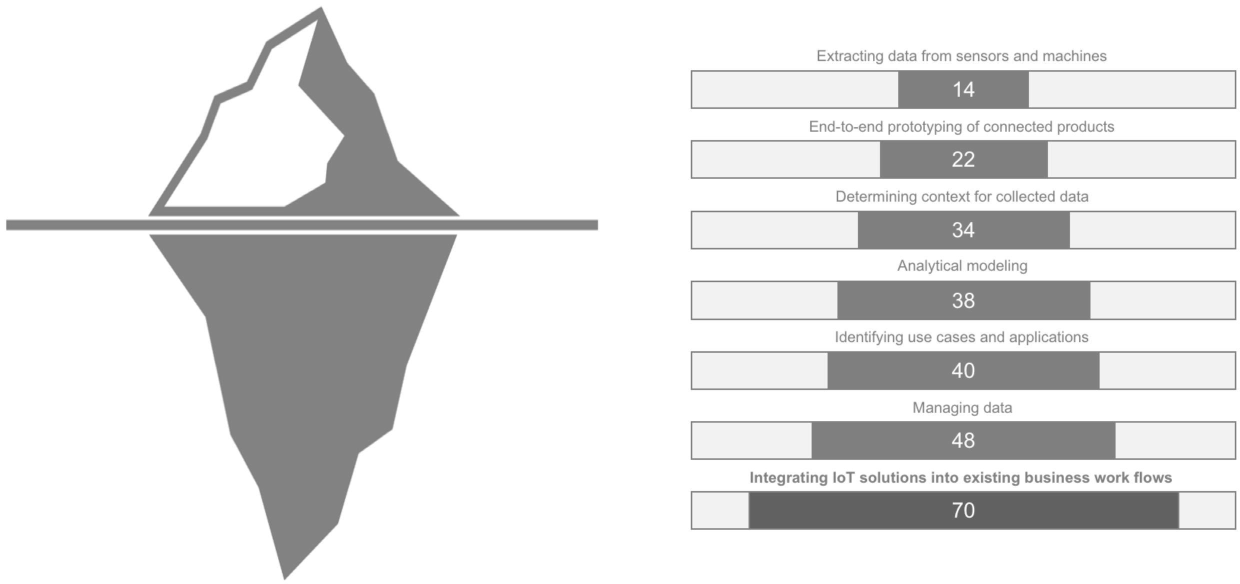

Figure 1: Companies have many capability gaps related to IoT (Adapted from https://www.mckinsey.com/global-themes/internet-of-things/our-insights/taking-the-pulse-of-enterprise-iot)

simulation laboratory that are connected to a predictive maintenance model which operates in a well-controlled and monitored environment. It is quite another to do that for 300 pumps with a variety of makes and models in a harsh refinery environment where connectivity and latency issues impact the quality of data received from the IoT hardware. Making IoT successful is not just solving engineering and interoperability challenges, but also improving the business and its processes.

Operational capabilities most often manifest in an organization's workflows or business processes, as the McKinsey survey highlights. Gartner Research[5] supports this notion. "Companies typically focus significant attention on instrumenting their 'things' and choosing an IoT platform hub to meet [Information Technology] IT project requirements. However, they underestimate the degree of impact that these projects will have on their applications. But IoT business solutions generally cannot be fully implemented technically or fully realized commercially until they are seamlessly integrated with relevant business applications to help improve core business processes."

The Cisco survey[6] shows that organizations are looking to use data from IoT projects to have a real impact on their business:

- Improved product quality or performance: 45%
- Improved decision-making: 46%
- Lowered operational cost: 45%

[5] https://www.gartner.com/doc/3447218/use-iot-platform-reference-model

[6] https://www.slideshare.net/CiscoBusinessInsights/journey-to-iot-value-76163389

- Improved or new customer interactions: 44%
- Reduced maintenance or downtime: 42%

A more important insight from the survey is the difference in perception of IT and business on the success of IoT projects. 35% of IT executives consider their IoT projects successful, while business executives only regard 15% of IoT projects to be successful. The survey also showed that IT executives placed more importance on technologies, organizational culture, expertise and vendors. Business executives on the other hand placed more emphasis on strategy, business cases, processes and milestones.

This chasm between IT and business is often the main reason for projects not moving beyond engineering PoCs, as the Cisco survey data shows. It is the reason why IoT fails to deliver the anticipated impact and improved operational capabilities.

Industrial IoT projects most often include an additional Operational Technology (OT) group and all three stakeholder groups need to work together to achieve the business objectives described above.

Business stakeholders are often subject matter experts (SMEs) with a technical background. These are often Operations Managers, Maintenance and Operations Engineers, Production Managers and Asset Managers. These SMEs understand the business problem they want/need to solve. They know the use cases and where the ROI (return on investment) is most likely to be realized. Many of them have a technical background, but they are not IT system developers or automation experts.

IT stakeholders, in turn, understands the business systems and applications that support the business operations. IT provides support services to the business such as cloud, network infrastructure, databases and business applications. IT management is primarily concerned with risk, governance and business support.

OT, on the other hand, uses similar infrastructure as IT but understands the operational technology, automation and "things." OT focuses on Machine to Machine (M2M) and Machine to Infrastructure (M2I) connectivity, control systems, Supervisory control and data acquisition (SCADA) and Programmable Logic Controllers (PLCs). OT management is concerned with automation, security, latency and operational optimization.

Many of the estimated 450 [7] new IoT platforms aim to cover the convergence of OT and IT technology but do not address the needs of business to integrate these IoT solutions into existing business processes or workflows.

These different perspectives all need to be addressed to deliver a successful IoT project that provides value beyond a PoC. The business processes that support the requirements of all three stakeholders needs extensible integration and interoperability to cater to the combined complexity of

[7] https://www.iothub.com.au/news/the-number-of-iot-platforms-jumps-to-450-467554

technology requirements from the three stakeholder environments (groups).

To deliver new IoT-enabled operational capability, this article proposes a practical framework that creates a shared understanding of: (1) the business case, (2) the solution architecture around integration, services and data flow and (3) the domain model.

PROBLEM SPACE

The challenges associated with extracting data from sensors and machines is less of a capability gap than leveraging the data from them, as can been seen from the McKinsey survey.

The goal of this framework is not to address the technical aspects of IoT integration such as connectivity, security and interoperability. These are key technical success factors for any IoT project and warrant comprehensive technical consideration that is beyond the scope of the business focus of this article. Instead, we aim to create a practical IoT to Operational Capabilities (I2OC) framework that tackles the following business challenges: (1) How do we describe and agree on the key business outcomes that an IoT solution will deliver, (2) How do we describe and agree on the business integration of heterogeneous machine-borne (IoT) data with existing business applications and (3) how do we describe and agree on the integration of IoT into existing business workflows.

Developing such a framework requires different perspectives or viewpoints and the Industrial Internet Consortium's Industrial Internet Reference Architecture [8] (IIRA) provides practical guidance on these viewpoints. These four viewpoints are: (1) business, (2) usage, (3) functional, and (4) implementation.

"The *business viewpoint* attends to the concerns of the identification of stakeholders and their business vision, values and objectives in establishing an [Industrial IoT] IIoT system in its business and regulatory context. It further identifies how the IIoT system achieves the stated objectives through its mapping to fundamental system capabilities."[9] The I2OC framework describes the stated objectives in terms of key business drivers and identifies the fundamental system capabilities needed to achieve these objectives.

"The *usage viewpoint* addresses the concerns of expected system usage. It is typically represented as sequences of activities involving human or logical (e.g. system or system components) users that deliver its intended functionality in ultimately achieving its fundamental system

[8] https://www.iiconsortium.org/IIRA.htm (version 1.8 accessed January 26, 2018)

[9] https://www.iiconsortium.org/IIC_PUB_G1_V1.80_2017-01-31.pdf (page 15)

capabilities."[10] The I2OC framework address the usage scenarios.

"The *functional viewpoint* focuses on the functional components in an IIoT system, their structure and interrelation, the interfaces and interactions between them, and the relation and interactions of the system with external elements in the environment, to support the usages and activities of the overall system." [11] Integration and interoperability between OT, IT and business applications is a key part of turning IoT technology into operational capability. The I2OC framework describe the high-level functional requirements for this integration.

"The *implementation viewpoint* deals with the technologies needed to implement functional components (functional viewpoint), their communication schemes and their lifecycle procedures. These elements are coordinated by activities (usage viewpoint) and support the system capabilities (business viewpoint)." [12] The I2OC framework provides high-level guidance on the technology approach for the integration of OT, IT and business applications into existing workflows or new business processes.

Two further concepts from the IIRA business viewpoint are used in the development of the framework to turn IoT technology into operational capability. "*Key objectives* are quantifiable high-level technical and ultimately business outcomes expected of the resultant system in the context of delivering the values. Key objectives should be measurable and time-bound. Senior business and technical leaders develop the key objectives. *Fundamental capabilities* refer to high-level specifications of the essential ability of the system to complete specific major business tasks. Key objectives are the basis for identifying the fundamental capabilities."[13]

The I2OC Framework

The I2OC framework combines a high-level IoT solution architecture with business outcomes and an implementation viewpoint to facilitate the collaboration of business, IT and OT. It is based on a value chain that starts with industrial assets and ends with desired business outcomes.

The value chain of the framework starts by defining the operational assets that impact the business outcomes for a specific scenario or use case. It could be a single asset such as a fin fan in a refinery, a collection of similar assets such as wind turbines in a geographic region or a complex system such as a CHPP (coal handling and processing plant) in a coal mine.

[10] https://www.iiconsortium.org/IIC_PUB_G1_V1.80_2017-01-31.pdf (page 16)

[11] https://www.iiconsortium.org/IIC_PUB_G1_V1.80_2017-01-31.pdf (page 16)

[12] https://www.iiconsortium.org/IIC_PUB_G1_V1.80_2017-01-31.pdf (page 16)

[13] https://www.iiconsortium.org/IIC_PUB_G1_V1.80_2017-01-31.pdf (page 21)

These assets or "things" typically have instrumentation or sensors that collect operational data and information. Plant historians or time-series databases are often used to aggregate this operational data. The framework can be adapted to cater to the specific infrastructure in an organization. The industrial assets and data sources represent the big data component where the raw data is collected and streamed or stored before it is integrated into a business use case or application.

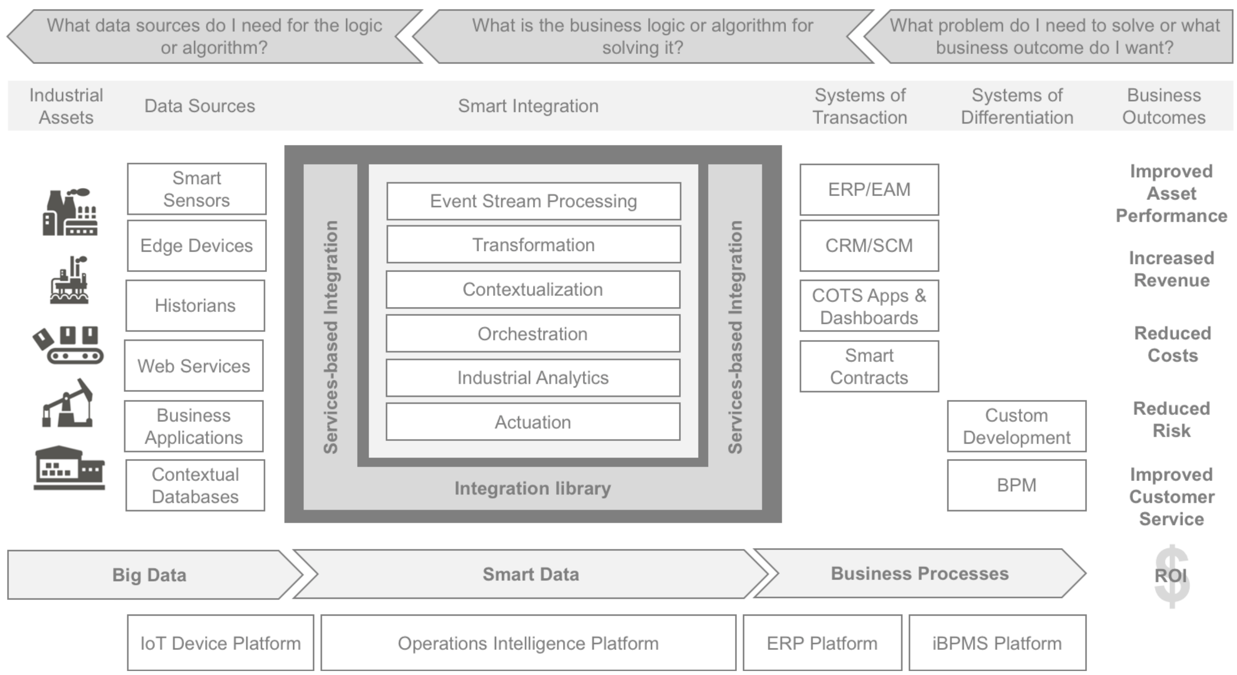

Figure 2 - I2OC (IoT to Operational Capability) framework

An enhanced integration approach is central to the framework. The integration "middleware" acts as the centralized integration library that contains OT, IT and business application integration components. This middleware is enhanced with event stream processing (ESP), data transformation and orchestration capabilities to not only integrate but also process and transform the near real-time data from the industrial assets before it is integrated into existing and new business workflows.

Gartner refers to this type of real-time integration and processing capability as Operations Intelligence platforms[14] that use standard adapters to read and write information from different devices, systems and applications. The level of processing capability differs among the different types of operations intelligence platforms, but it typically includes the ability to stream or poll data from real-time systems, perform some level of event stream processing and orchestration before integrating the processed data back into operations. This

[14] https://www.gartner.com/doc/3540217/market-guide-operations-intelligence-platforms

processing capability typically turns big data into smart data as shown by the chevron arrows on the framework diagram (Figure 2).

The functionality of operations intelligence platforms can be achieved by combining different standalone integration, ESP and analytics applications, but it introduces additional complexity in the solution architecture that is required for an IoT-enabled process application.

The final stage of the value chain integrates the smart data into operational business processes that deliver the desired business outcomes. Gartner's Pace-Layered [15] application strategy provides some high-level guidance on how to achieve this. It differentiates between typical "Systems of Record or Transaction," "Systems of Differentiation" and "Systems of Innovation." The latter tend to apply to the POC phase of IoT applications and once the innovation is established it can be integrated into the day-to-day business workflows to provide a system of differentiation. The I2OC framework categorizes business applications into the systems of transaction and systems of differentiation. ERP, EAM, CRM and other COTS (commercial off-the-shelf) solutions are typically systems of record or transaction, whereas custom developed applications and business process management tools provide the differentiation.

Blockchain is a new generation transactional ledger that is making its way into business and IoT solutions. Blockchain-based "Smart Contracts" as a system of transaction represent new architectures for distributed processes or new applications and business models. "Smart contracts can be used to provide an implementation of a workflow or payment instrument, moving virtual currency around as the situation dictates."[16]

The objective of an industrial IoT solution is not to have connected assets or devices, but to deliver on specific business outcomes that will improve operations and competitiveness. Creating a shared view and understanding of the desired business outcomes for a specific IoT project is a critical success factor in ensuring that projects are not regarded as failures and move beyond the PoC stage as described in the Cisco survey.

The IO2C framework categorizes the business outcomes as (1) improved asset performance, (2) increased revenue, (3) reduced costs, (4) reduced risk and (5) improved customer service. These are typical benefits associated with industrial IoT solutions and can be adapted to the specific requirements of an organization.

Technical project leaders typically start on the left of the value chain with the assets and sensors, while business leaders tend to start on the right hand side and define the requirements in terms of the expected

[15] https://www.gartner.com/binaries/content/assets/events/keywords/applications/apn30/pace-layered-applications-research-report.pdf

[16] http://www.chainfrog.com/wp-content/uploads/2017/08/smart-contracts.pdf

business outcomes. This is also the starting point for using the I2OC framework. The top row of chevron arrows first addresses the business requirements before defining the technical infrastructure to achieve them. Three basic questions are used as the basis for establishing common objectives between all the stakeholders: (1) What outcome do we want, (2) what processes or business logic will deliver that and (3) what data do you need for that? This approach focuses on the problem at hand and identifies the key data sources needed, rather than looking at what sensors and data organizations have and then trying to retrofit them to the problem. This approach supports the business viewpoint of the IIRA.

The I2OC framework is used to address the three challenges of agreeing what success looks like, how to manage complex data integration from heterogeneous sources and how to make it part of the day-to-day operations in industrial organizations. The following section describes how the framework is used to address each of these challenges.

XMPRO Business Value Assessment

#	Use Case/Scenario	Business Impact					Economic	Technical Feasibility				
#	Use Case/Scenario	Safety	Downtime	Throughput	Quality	Cost	Value/year	Automation	IT Systems	Analytics	Environment	Project
1	Use Case 1	Medium	High	High	High	High	> $10m	High	High	Medium	High	High
2	Use Case 2	Low	Low	Medium	:ustomer satisf	High	> $10m	High	High	Low	High	High
3	Use Case 3	Low	Low	Low	Low	Low	> $1m	High	High	Low	High	High
4	Use Case 4	Low	Low	Low	Low	Low	> $1m	High	High	Low	High	High
5	Use Case 5	Low	Medium	High	Low	Medium	> $10m	Medium	High	Low	High	High
6	Use Case 6	Medium	Medium	Medium	Medium	Medium	> $1m	High	High	High	High	High
7	Use Case 7	Low	Medium	Medium	Medium	Low	> $1m	High	High	High	High	High
8	Use Case 8	Medium	Medium	Medium	Medium	Medium	> $10m	High	High	High	High	High
9	Use Case 9	Medium	High	High	High	High	> $1m	High	High	High	High	High
10	Use Case 10	High	Medium	Low	High	Low	> $1m	Medium	Medium	Medium	High	High

Figure 3 - Business Impact ranking matrix

Framework to Agree on Key Business Outcomes

The high-level business outcomes in the I2OC framework are the basis for scoring and agreeing on the business impact of a specific IoT-enabled use case. It is often useful to list a number of potential scenarios or use cases and rank them based on their business impact for each desired business outcome.

To avoid analysis paralysis[17] a simple high, medium and low scoring methodology is used in setting up a ranking matrix. This is best done with the business (operations), IT and OT representatives in a working session. It is also useful to score the technical feasibility (or complexity) for each scenario, again without over-analyzing or getting into too much technical detail.

In this example, the following technical assessment criteria is used: (1) OT complexity, (2) IT complexity, (3) analytics, (4) system complexity and (5) project readiness.

OT and IT complexity, in turn, is described in terms of availability, accuracy, latency and

[17] https://en.wikipedia.org/wiki/Analysis_paralysis

geographical location. Analytics is described in terms of maturity, sophistication (predictive and cognitive analytics) and application of business rules or physical models. System complexity is based on deployment infrastructure (edge, local and cloud) and geographical constraints. Project readiness is assessed based on availability of subject matter experts and technical resources.

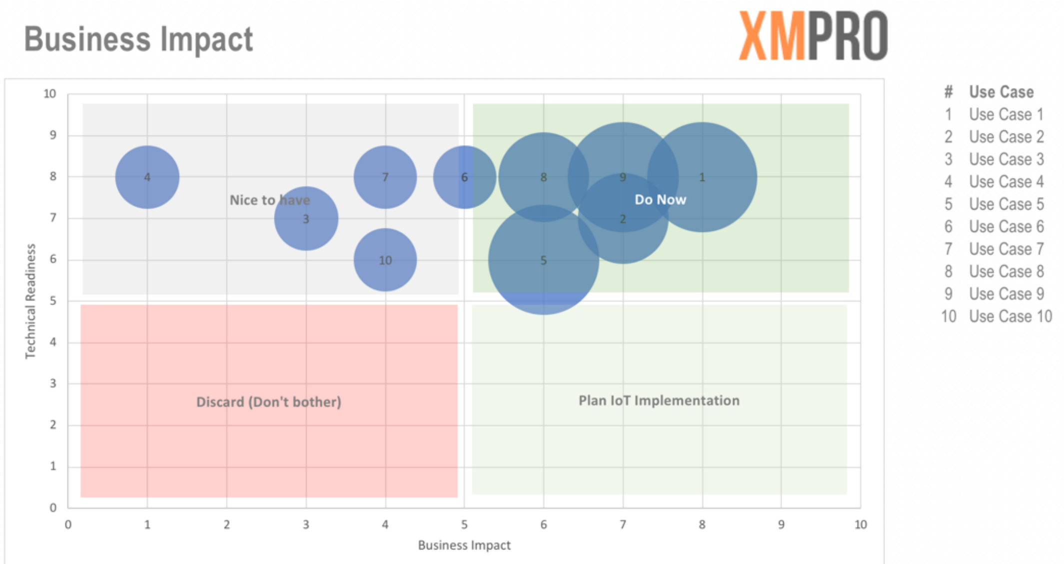

Figure 4 - Bubble chart that visually ranks IoT Projects based on business impact and readiness

It is generally useful to define "order of magnitude" financial measures to agree on the high-level impact of each new state or scenario. The objective is not to be accurate in estimating the value of a business case, but to get high-level agreement between the different stakeholders on the potential impact of each scenario. In this example a scale of (1) greater than $100k, (2) greater than $1m or (3) greater than $10m is used.

This can be visually represented in a bubble chart with business impact and technical readiness as the two major measures. The weighted average values of each of the measures are placed on the graph which is divided into four quadrants. The size of the bubble is determined by the value of the economic impact. The four quadrants represent the business readiness for each of the scenarios. The "Do Now" quadrant represents high business impact and a high level of technical readiness. Opportunities on the far right of the quadrant with the biggest bubble size often represent IoT projects with the highest likelihood of success for all stakeholders.

This approach provides a common understanding of the expected business outcomes and potential technical challenges in achieving this goal. It provides the basis for more detailed analysis of those projects with a high likelihood of success. This analysis aims to address the remaining two questions in the I2OC framework: (1) what is the business logic or algorithms for solving a business problem and (2) what data sources do I need for the logic or algorithms?

The latter describes the second challenge in turning IoT solutions into operational capability as discussed above.

Framework to Agree on Integration of Heterogeneous IoT and Business Data

In 2009, Patrik Spiess[18] et al. presented a vision for SOA-based integration of IoT in enterprise service. "... [F]uture infrastructures will be service-oriented. As such, new functionality will be introduced by combining services in a cross-layer form, i.e., services relying on the enterprise system, on the network itself and at device level will be combined. New integration scenarios can be applied by orchestrating the services in *scenario-specific* ways."

The I2OC framework provides a mechanism to describe the unique integration and orchestration for each scenario or use case as an independent IoT business application.

This is done in a visual, model-driven approach where business applications are constructed through a drag-and-drop user interface where data from IoT sources are integrated with analytics and business workflows and applications.

In their approach, Spiess et al. use web services as the primary integration technology to allow networked devices that are connected through middleware to directly participate in business processes. Data protocols for OT, IT and business applications have evolved since Spiess

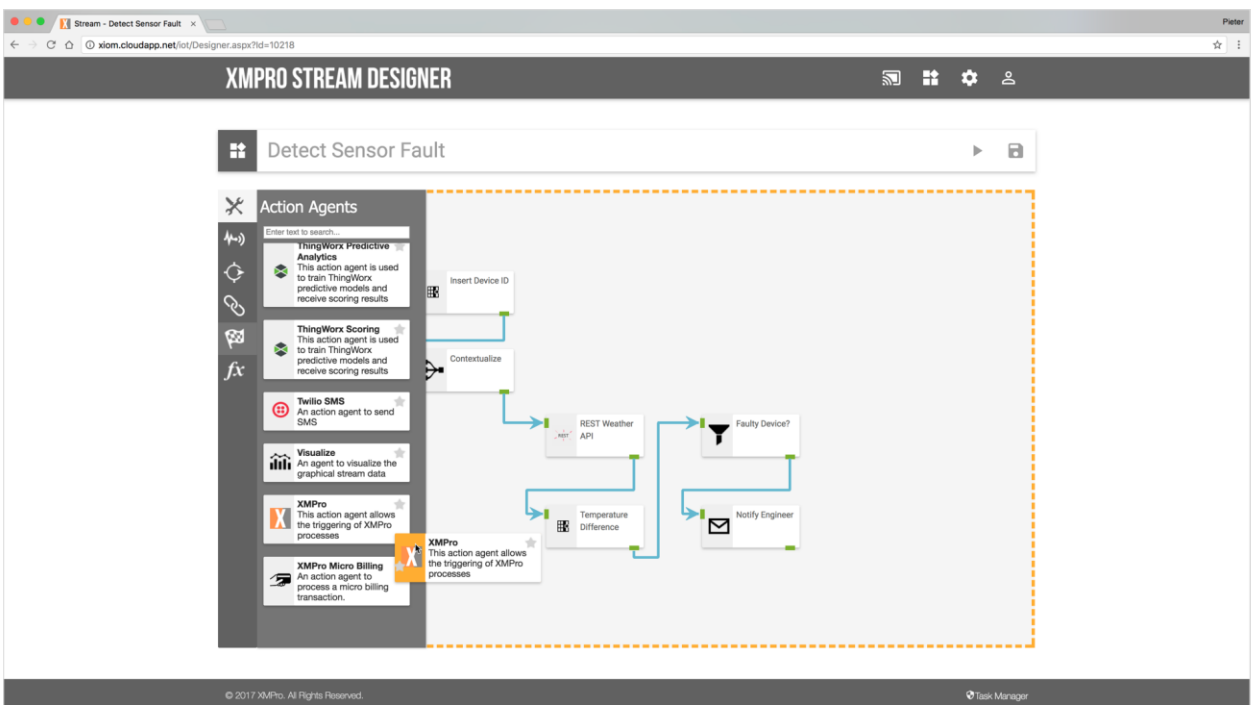

Figure 5 - A visual, model-driven approach connects IoT data sources to analytics and business workflows

[18] http://ieeexplore.ieee.org/abstract/document/5175920/

published the SOA-based integration vision. Web services (SOAP) is currently one of a number of different integration services alongside web APIs (REST) for example. The emergence of IoT protocols [19] introduced a plethora of new data integration options. MQTT, XMPP, AMQ, OPC-UA, DDS and LLAP are but a few of an ever-increasing list of IoT technology that need to be integrated into existing business workflows. Spiess' vision for a scenario-based, SOA-enabled integration of the Internet of Things provides the basis for the I2OC framework that extends integration beyond web services and proposes a centralized library with integration objects for OT, IT and business application integration protocols. These library objects, in conjunction with orchestration rules, are used to construct business-focused use cases or scenarios.

The I2OC framework uses a Smart Integration approach that combines typical middleware integration with event stream processing, data transformation, orchestration, advanced analytics and business rules.

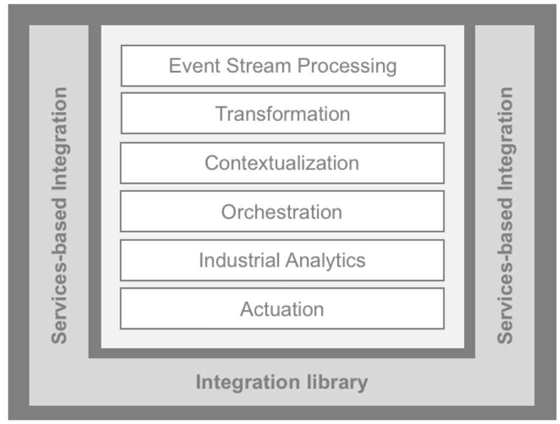

Figure 6 - The I2OC Smart Integration approach

The smart integration is based on a central library concept that contains the integration technology for all the OT, IT and business applications required for all IoT-enabled use cases. Such a central library not only provides a single repository of integration services, but it addresses some of the main concerns for OT and IT stakeholders around the security and trustworthiness of the IoT infrastructure.

Services-based integration components are wrapped in library containers and then used as integration objects in a model-driven, visual integration workflow. These integration objects are used in a drag-and-drop user interface to construct specific integration sequences or event streams. These integration sequences are further enhanced to also provide event stream processing, orchestration and other data transformation capabilities that turns it into "smart integration".

[19] https://www.postscapes.com/internet-of-things-protocols/

The integration objects are classified into different functional areas in the example below. Integration objects that can poll or stream data from the sources described in the I2OC framework are referred to as *Listeners* while objects that create actions in business applications such as ERP and EAM solutions are grouped as *Action Agents*. Commercial Operations Intelligence platforms describe and categorize their integration components or connectors with different nomenclature.[20]

models that act as standalone objects (such as a Fast Fourier Transformation for vibration analysis) can also be created and published to this centralized integration library.

In addition to the technical benefits of a single and centralized integration repository, this approach helps with the collaboration and understanding among the different stakeholders of the integration requirements. By visually mapping out the

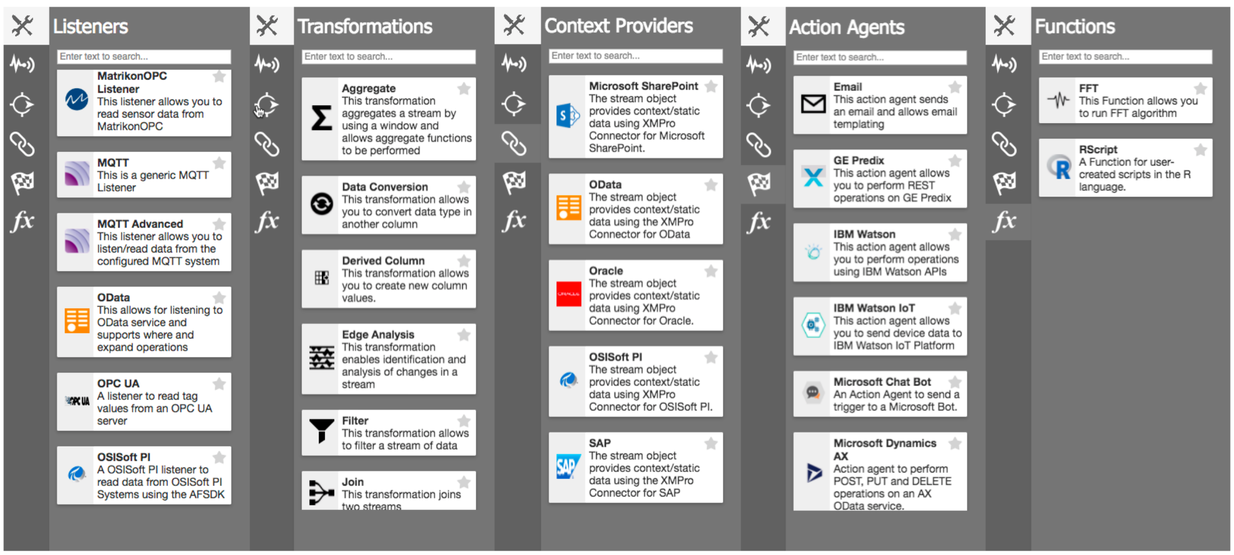

Figure 7 – Drag-and-drop integration objects in a central, extensible library.

The central library concept applies to all input, context and output integration connectors processed with the lifecycle management of these integration points. Wrapping these service-based integration components in the library containers further provide a mechanism for extensibility. New or modified connectors can be generated by OT and IT specialists and placed in the library. Customized functions and physical data inputs, contextual information, or data outputs and actions, there is a common understanding of the business logic and data is required to deliver the desired business outcomes. It highlights areas where data or systems may not exist, and projects are likely to fail.

The visual mapping process furthermore creates an understanding of how a particular scenario will fit with new or existing

[20] https://www.gartner.com/doc/3540217/market-guide-operations-intelligence-platforms

applications to support business workflows. Integration is a critical success factor for highly technical IoT solutions that need to support the work operations personnel perform on a day-to-day basis.

Framework to Agree on Integration of IoT into Existing Business Workflows

The McKinsey report referenced earlier, shows that integrating IoT solutions with existing business workflows is the area with which most organizations struggle.

The notion of integrating IoT into business processes is not a new one. Meyer[21] et al presented an extension of the BPMN (business process modeling notation) at the International Conference on Advanced Information Systems Engineering in 2013 that describes IoT devices as business process resources. "Typical enterprise solutions such as ERP systems could benefit from the integration with the IoT, if business process-related devices such as RFID, sensors and actuators could directly take over responsibility as process resources for individual process tasks."

The BPMN extension provides a mechanism to model these new process participants in a machine-readable model, but it doesn't deal with the two IoT process characteristics that result in organizations struggling to implement IoT-based business processes.

Firstly, traditional business processes are mostly initiated as requests (request-driven business process management) whereas IoT-based business processes are based on real-time events (event-driven business process management). Schulte and Chandy [22] describe the event-driven approach as a combination of complex event processing (CEP) and business process management (BPM). "CEP software can identify a threat or opportunity situation that triggers a new business process instance." Their work only focused on the IT applications domain and IoT integration brings an added dimension of complexity to IoT-based processes or workflows. IoT data sources require some form of preprocessing to reduce the volume and velocity to only those events that require business process intervention. This is not traditionally done by business process management tools in organizations.

Secondly, new IoT business models require composite processes that are orchestrations of actions rather than monolithic processes on a single process platform such as an ERP or BPMS system. These systems now become elements of new macro processes that support business model innovation and other opportunities that come with leveraging IoT.

The I2OC framework recognizes these challenges and suggests a higher order mapping of the business processes that include applications like ERP and BPM systems as components rather than the process platforms.

The following example describes this higher-level approach.

[21] https://link.springer.com/chapter/10.1007/978-3-642-38709-8_6

[22] Event Processing: Designing IT systems for agile companies - McGraw-Hill 2010 (page 171)

The data stream leverages the integration library described in the previous section. Data from streaming IoT data sources and other business applications are brought in with listeners. In this example, data from a DDS control system (streaming data) is combined with SAP asset information (context) and additional information is added to the event stream from a commercial historian system. All the temporal and contextual information is joined based on a timestamp. This data stream is then multi-casted to two parallel operations. The first identifies KPIs that are out of bounds (based on defined business rules) and this is again multi-casted to a standard dashboard visualization tool as well as a parallel task to create a work order in the ERP or EAM solution for a field crew to investigate the issue. A Non-Conformance Report or NCR with a corresponding Root Cause Analysis workflow is generated in a BPMS tool.

The second leg of the original data stream calls a cloud-based predictive model to predict the change in other KPIs and a chatbot interacts with the operations team on the impact of the event data. This example combines IoT and application integration with orchestration, advanced analytics, actuation, contextualization and real-time data transformation in a distributed deployment environment. It extends beyond visual models, as the event stream is executed by the "play" button at the top of the user interface.

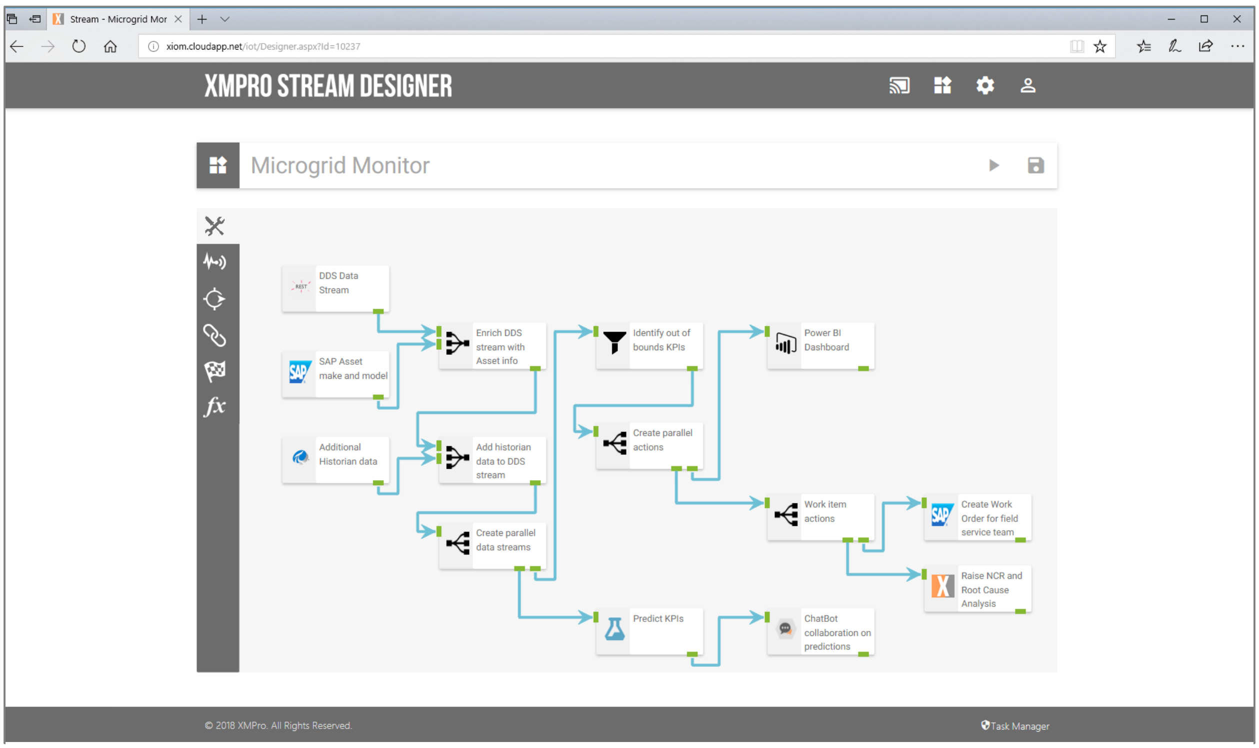

Figure 8 - Example of an event stream that integrates IoT data into operational workflows

The example demonstrates how event information from IoT data sources is pre-processed before it is integrated to existing workflows for systems of transaction such as the ERP solution as well as new systems of differentiation such as the NCR or chatbot.

USE CASE IMPLEMENTATION

An upstream division of a Fortune 10 Oil & Gas company in North America saved $8 million in a period of six months after deployment of this I2OC approach. The savings were calculated during a 6-month review of the project after "go-live." It also resulted in an 18% reduction in field service trips for a specialized crew. This reduction directly impacted safety which is a key measure of success that is not quantified in monetary terms.

The solution was deployed into production within 90 days from the start of the project using the re-usable library and visual design approach of the I2OC framework. The initial estimate for a custom-developed solution exceeded 9 months.

The intellectual property of the solution is proprietary to the company but the application of the I2OC framework approach can be described at a high level.

The desired business outcome of the solution is to improve the scheduling of specialized crews, to improve the first-time fix rate, reduce production losses due to regulatory inspection and maintenance downtime and improve the safety of workers. This was the first step in applying the framework (Figure 9, circle 1). Proprietary scheduling algorithms can provide the desired outcomes if accurate data is provided to these algorithms in time (circle 2). By understanding what data these algorithms and business rules required, the team could identify the appropriate sources that would support this (circle 3).

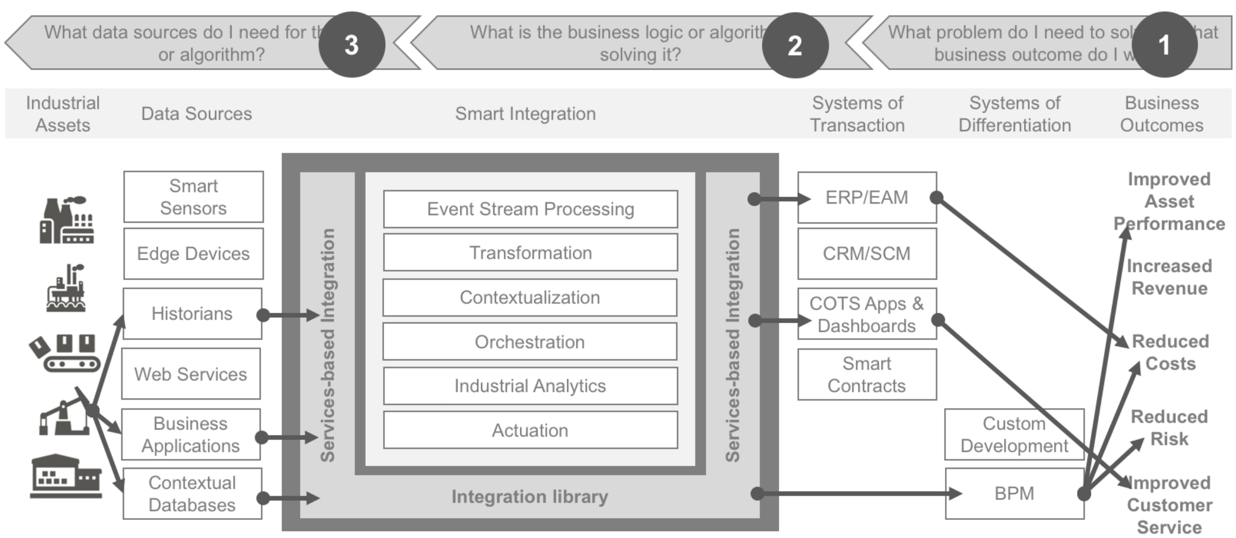

Figure 9 - Practical application of the I2OC framework for a Fortune 10 Oil & Gas business

Conflicting data from different operational and business data sources made accurate crew scheduling a challenge. Data accuracy, latency and quality is improved by combining near real-time data from operations historians with production and operations systems. This is depicted with the arrows that connect the well with the historian, business applications and contextual databases. In practice the specific data sources are listed below the diagram to communicate the requirements to all stakeholders.

The scenario-specific event stream has the specific data sources on the canvas and the business logic and orchestration is composed to transform the data into information that is integrated with existing asset management systems. The crew scheduling system is created in a BPMS solution that provides the system of differentiation and also manages the field service teams. This is depicted by the arrows from the smart integration block on the I2OC framework that extend to the systems of transaction and differentiation. Each of these are, in turn, mapped to specific business outcomes. It demonstrates an end-to-end example of turning IoT technology into operational capability.

Conclusion

The Internet of Things (IoT) is quite often associated with thousands of smart devices and innovative sensors, blinking LED's and data streams that provide gigabytes of data to smart IoT dashboards.

Business stakeholders and IT management currently differ in their perspectives on the success of IoT solutions, but the same Cisco survey found that more than 60% of IoT projects do not move beyond the PoC phase. McKinsey research found that more than 70% of their survey respondents identified the integration of IoT solutions with existing business workflows as a major capability gap.

The I2OC framework described in this article is based on the Industrial Internet Consortium's IIRA that describes the complexity of industrial IoT solutions from business, usage, functional and implementation viewpoints. It provides a collaborative approach to define and agree on business outcomes, the business logic that will deliver the outcomes and the integration that turns IoT technology into operational capability.

Future work on the I2OC framework may include the expansion of the model to include perspectives from other initiatives such as Industrie 4.0 and the development of additional criteria around security and trustworthiness.

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