fybr®

People. Places. Connected.

An Enterprise Internet of Things platform that spans wireless devices to cloud servers, enabling rapid development and deployment of connected solutions that improve the way we live and work.

TABLE OF CONTENTS

A NEW DIGITAL **REVOLUTION**

Behind the scenes at the world's leading cities and enterprises, a profound revolution—a digital revolution—is underway.

While the market is full of buzzwords attempting to capture this phenomenon, three concepts underscore the vision and mission we have undertaken at Fybr.

Digital Transformation: According to Capgemini Consulting[1], digital transformation is "The use of technology to radically improve performance or reach of enterprises." Modern innovation in Machine Intelligence, Big Data, and Connected Networks can help businesses re-envision customer experience, operational processes, and business models.

Industry 4.0: Focuses on the end-to-end digitization of all physical assets and integration into digital ecosystems. PwC[2] highlights, "These developments will fundamentally change individual companies, as well as transform market dynamics across a whole range of industries." Seamlessly collecting, analyzing and communicating data underpins the gains promised by Industry 4.0.

Internet of Things (IoT): Proliferation of sensors and ultra-low cost connectivity, together with powerful analytics are transforming services and business models across sectors. McKinsey Global Institute states[3], "By bringing machines and assets into the connected world, the Internet of Things enables new ways of monitoring and managing all the moving parts that make up businesses and communities."

By bringing machines and assets into the connected world, IoT—and particularly Industrial IoT—enables new ways of monitoring and managing all the "moving parts" that make up businesses and communities, creating an economic impact of $2.7 trillion to $6.2 trillion annually by 2025.

Some of the most promising uses are in infrastructure and public-sector services—helping society tackle some of its greatest challenges. The ability to monitor and control power grids and water systems can have major impacts on energy conservation, greenhouse gas emissions, and water loss. By using sensors to streamline operations, public-sector functions such as garbage collection can become much more productive.

But before this transformation can become a reality, businesses must recognize and tackle the complexity of IoT solutions to ensure secure, scalable, and interoperable deployments.

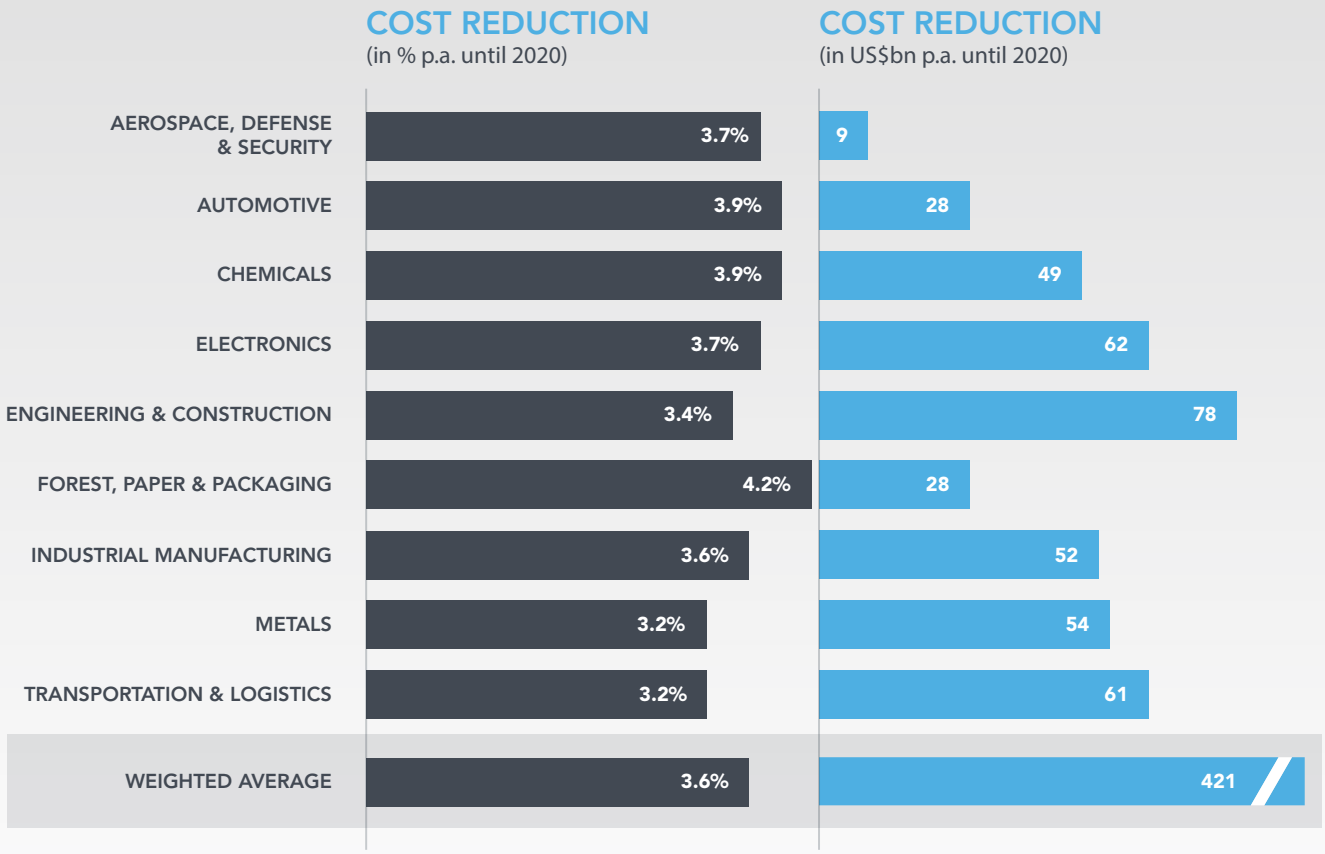
Fybr has built and proven a technology foundation that reliably, efficiently, and quickly integrates physical assets into enterprise processes. We help cities and companies make customers happier, optimize operations, and make better decisions.

QUANTUM LEAPS IN **PERFORMANCE**

PWC's 2016 Industry 4.0 Survey[2], with over 2,000 participants from nine major industrial sectors and 26 countries, concluded: "digitization will drive quantum leaps in performance." The survey found that "high levels of **cost reduction** are expected in every industry sector" and "on average, companies expect to reduce operational costs by 3.6% p.a." while survey participants "expect **additional digital revenues** of 2.9% p.a. until 2020."

A similar study conducted by the World Economic Forum (WEF) and Accenture[4] concluded that "digital initiatives could generate an estimated **$100 trillion in economic value** over the next decade."

The WEF study and other analyses like Gartner's Fifty Examples of Digital Business[5] strongly suggest that enormous economic value can be generated by leveraging technologies like IoT, big data, advanced analytics, and machine learning to hyper-personalize customer experiences, reduce operational inefficiencies, and innovate business models.



Source: PWC - Industry 4.0: Building the digital enterprise

While the specifics are unique to different sectors, the framework remains similar and can ultimately be reduced to **increasing revenue** and **decreasing costs**. There are abundant examples of various public and private organizations saving or making money with digital initiatives:

- Manufacturers that have deeper visibility across their supply chains can charge a premium for rapid product delivery or can change product focus more nimbly than their competitors.

- Cities that sense parking and traffic can dynamically change parking rates to meet changing demand, modify traffic patterns based on congestion, and increase retail revenue—all from the intelligent use of real-time and historical parking data.

- Companies that can orient their business around real-time sensing and predictive maintenance often develop the ability to disrupt traditional business models. For instance, Kaeser Kompressoren[5] is moving away from selling air compressors towards selling air-as-a-service.

Finally, businesses can use the granular information to design and develop new products with digital features to augment their existing portfolios; this leads to new revenues and improved operating margins. Some examples include 3M's Bluetooth connected digital stethoscope, Oakley's augmented-reality ski goggles, and Diageo's sensor-enabled smart bottles, all of which have taken existing product lines and extended them to create products and services with higher margins.

THE NEW COMPETITIVE **LANDSCAPE**

Regardless of industry vertical, the pressure to transform will only continue to grow.

Government agencies are being driven by increased pressures to reduce costs and deliver a better quality of services. At the same time, governments will be strongly influenced by the open data movement to increase transparency and citizen demands to provide personal data privacy and protections.

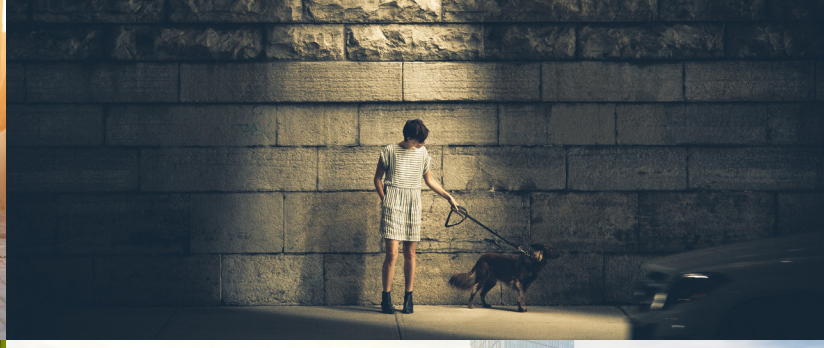
Private sector companies are being pressured by their shareholders and their competitors to adopt approaches to business transformation. Whether the drivers are cost cutting and efficiency, or pressure to increase revenue, the market will reward companies that make use of these new tools to innovate and transform themselves and their industries.

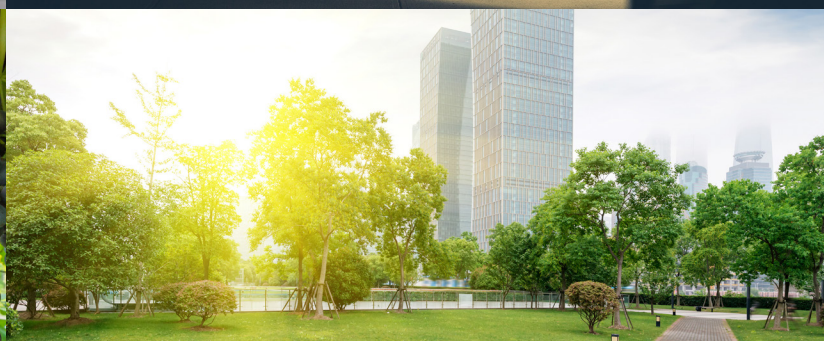
Fybr, in multiple large-scale deployments, has proven a set of tools that enable companies and governments to exploit opportunities created at the intersection of digital information and the physical world.

Fybr's turnkey solutions address the most challenging barriers to adoption faced by mature companies as well as startups—offering templates for success and in some cases, whole business models that can be readily taken to market.

Efficiency gains of the magnitude uncovered by our survey have the potential to change the competitive landscape within a very short space of time. If even half of the expectations outlined are realized, some companies may find themselves unable to compete. In an increasingly cost-competitive market, no industrial company can afford to lose out in operational efficiency against their market peers. The next two to three years will be crucial for companies looking to catch up.

PWC: 2016 Global Industry 4.0 Survey



Managing the real-world with IoT.

Transportation

- Monitor parking spaces to determine when they are empty or the meter has expired.
- Monitor traffic flow and alert law enforcement when cars are parked in restricted areas such as fire hydrants or other no-parking zones.
- Monitor buses, delivery vehicles, public safety assets, etc. to determine location, patterns, etc.

Utilities

- Turn on street lights only when there is a car or pedestrian passing by to save cities power and money, or dim lights to save power when the motion sensors are idle.
- Monitor water pipes for leaks and flow rate.
- Monitor sewer flow and detect backups.
- Monitor energy usage for commercial and residential applications.
- Place sensors along a gas line to detect leaks and reduce accident risks.

Oil and Gas

- Remote asset monitoring and system alert tools for off-grid applications.

Public Space

- Use sensors in the soil to help determine when grass and other landscape needs watering.
- Sound and crowd measurement for public safety applications.

Structural Integrity

- Use sensors to determine ground movement and vibration.
- Apply sensors to bridges, roadways, and buildings to measure stress, strains, and deterioration.

Agriculture

The 2015 Food Safety Modernization Act is pushing the food industry to deploy sensors at scale as part of regulatory reporting and compliance rules to create better local real-time sensing, reporting and prediction—monitoring and controlling things like:

- field conditions
- irrigation controls
- detailed weather
- shipping, storage time and other logistics

Pharmaceuticals

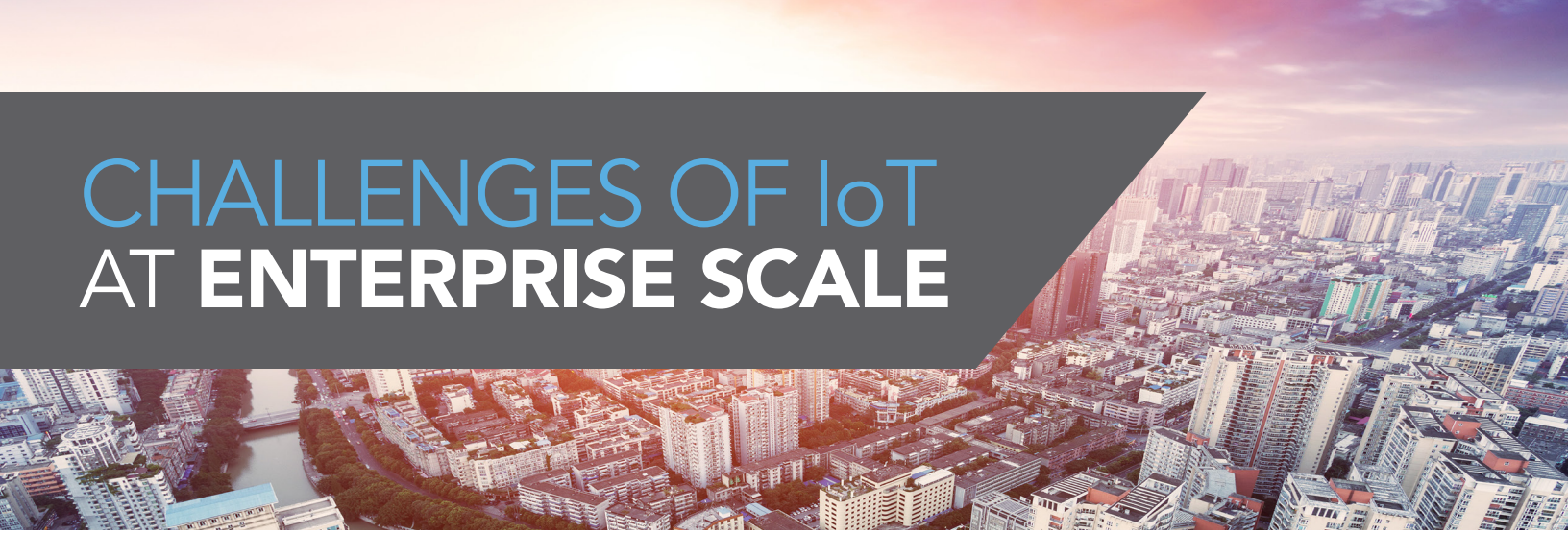
As part of the Drug Supply Chain Act, going into effect in late 2017, manufacturers will be requierd to monitor and track information across the value chain, including:

- Manufacturing, shipment, and storage data

Weather Sensing

- Monitor precipitation, humidity, barometric pressure, and air and ground temperatures.

CHALLENGES OF IoT AT **ENTERPRISE SCALE**



Fybr's Competitive Advantages

Forward-looking businesses are beginning to realize that tremendous value can be harnessed by exploring the increasingly blurred space between the connected world of digital information and the physical world where we live and work.

With IoT pilots and experiments proliferating, even the most established and well-run companies often underestimate the challenges in implementing IoT solutions for business-critical, large-scale, real enterprise scenarios.

Fybr's tightly integrated technology stack has been proven to tackle these challenges successfully while enabling a fast path to ROI for IoT projects.

Scale of data and integration complexity

Connected devices create volumes of data, which are unprecedented in traditional enterprise systems.

Cisco estimates[6] that the total volume of data generated by the Internet of Things will reach 600 Zettabytes per year by 2020, which is 275 times higher than projected traffic going from data centers to end users/devices (2.2 Zettabytes) and 39 times greater than total projected data center traffic (15.3 Zettabytes).

Understanding data of this size in the context of enterprise transactions and transforming it into actionable information mandates a data storage, integration, and analysis infrastructure that is designed from the ground up to handle these volumes, cut across silos, and produce results within time spans that deliver an advantage to the business.

Fast moving data and decision latency

In addition to being large-scale, device data moves rapidly. The speed at which 10,000 human users can create data is orders of magnitude slower than the rate at which 10,000 automated devices can produce messages. Enterprise systems that were traditionally designed to handle thousands of simultaneous user transactions may now have to respond to millions of device events.

To remain efficient, systems must be capable of comprehending data moving at much higher velocities while business processes need to be redesigned for faster decisions and quicker reaction time.

Real world conditions and sensing accuracy

In most applications, the only way to accurately sense a physical event or condition is to use learning algorithms that can be individually tuned to the surroundings of a particular device in a network that may contain thousands of similar programmable devices. To add further complication, environmental conditions may change over time, requiring constant adjustments to maintain accuracy.

Sustained accuracy and reliability is only achievable by enabling the sensing algorithm to learn and evolve with environmental conditions and business context.

Location specific power constraints

Many urban, industrial, and agricultural IoT applications envision devices in areas where providing power can be a challenge. Additionally, power consumption can be a crucial element in the successful implementation of a remote IoT system. Sensors and actuators installed in underground or remote pipelines, inside road beds, inside containers, etc. are all examples of devices that must depend on either battery power or must somehow harvest enough energy from their environment.

In either case, these devices must be designed to be extremely efficient in their use of power. Many of these applications can only be served by low data-rate, low-power edge devices that have been specially engineered to operate in such environments, as communications are often the biggest single factor in an edge device's power consumption.

Network reliability in urban and industrial environments

Similar to power constraints, wired network connectivity is not feasible in many scenarios, requiring IoT solutions to rely on wireless networks that have an extremely low-power footprint. Poorly designed protocols, bloated messages or inefficient encodings can all prove to be difficult engineering hurdles.

Moreover, industrial and urban environments are often affected by radio/electromagnetic noise or physical obstructions. Industrial IoT networks must be designed to adapt to such noisy conditions while providing redundant communication paths without compromising system power efficiency.

Device collaboration

Often, the information an IoT application requires cannot be confirmed by just one device. For instance, to detect a blockage in a sewage system, information from multiple sensors must be read collectively.

IoT systems must enable this type of concurrent collaboration between edge devices. Sometimes this communication is direct, over physical channels like radio, at other times it may require coordination at a central server. Direct communication may be instantaneous but can come at a significant power cost. Centralized collaboration may help reduce power consumption and enable cooperation between devices, but may increase latency.

Direct vs. central collaboration can present a range of trade-offs between power consumption, latency, and cost. A modern solution must empower applications that can prioritize any of these factors based on the appropriate business need.

Provisioning and maintaining thousands of distributed devices

Building, installing, and operating a network of connected things with tens of thousand of geographically distributed devices can present unique logistical challenges. Ensuring quality of service requires a system that can precisely track the entire life-cycle of each device from manufacturing to recycling.

- Before installation, such a system must track firmware versions loaded on each device, record unique identifiers, generate encryption keys, and record results of manufacturing quality checks.
- During installation, information such as when a device was installed, which team installed it, the exact install location, configuration, and activation time must all be collected.
- In operation, any significant event, maintenance activity, configuration history, firmware version history, suspicious event, etc. must all be tracked to enable future diagnosis and audits.

Flexibility, adaptability and risk in updates

Adopting the Internet of Things is a strategic investment for any enterprise. It is not enough to only consider short-term needs. IoT deployments must adapt to changing requirements while supporting future connected solutions that have yet to be created.

Initial IoT projects will often be experimental; therefore systems must enable simple and safe iterations, allowing teams to improve business logic and discover the best way to integrate physical world data into their processes.

IoT systems must also be flexible enough to easily integrate new sources of internal or external data that may offer additional business context.

To facilitate these evolutions, over-the-air firmware updates for remotely deployed devices is a critical, yet highly risky operation, traditionally leaving a system open to device failure and security vulnerabilities. A poor implementation may allow for bad updates that may, in turn, render a device inoperable or unable to communicate, or even render an entire IoT device network unusable—requiring costly repair efforts and potentially lengthy downtime.

To be successful, IoT solutions must enable a safe method of efficiently updating remote devices without leaving the business critically vulnerable.

System security

A 2016 paper by the US Department of Homeland Security (DHS)[7], on IoT device security, states that "Many of the vulnerabilities in IoT could be mitigated through recognized security best practices, but too many products today do not incorporate even basic security measures. There are many contributing factors to this security shortfall. One is that it can be unclear who is responsible for security decisions in a world in which one company may design a device, another supplies component software, another operates the network in which the device is embedded, and another deploys the device."

While it is essential to enforce established enterprise security practices with strict authentication, careful access management, granular network policies, etc., it is also prudent to avoid ad-hoc piecemeal solutions where there is no well-defined owner of security for the entire loosely integrated stack of technologies.

IoT solutions also present many new security challenges.

Mainstream authentication and encryption protocols are far too computationally expensive for most low-power wireless devices. Asymmetric algorithms are often impractical, while symmetric encryption presents complex key distribution and key management challenges.

Further, many IoT devices installed in urban and industrial scenarios are not protected by physical boundaries, leaving them vulnerable to tampering. This makes it hard for such edge devices to guarantee safe storage of keys. These challenges make robust key life-cycle management crucial to ensuring unique keys for every device. Additionally, new approaches to detect tampering and take remedial actions are necessary for sustaining a secure and reliable system.

Technology landscape fragmentation

There are many IoT solutions available on the market; however, most vendors provide only a subset of the components required to implement an integrated end-to-end solution.

Some vendors provide just the edge devices, others provide just the low-power wireless network, while many others sell "IoT platforms" which, in most cases, are just the centralized software-only server component with management tools.

Often, system integrators cobble together edge devices, wireless networks, and server-only IoT platforms to build a solution. As noted above, such piecemeal solutions often suffer from security issues due to the tremendous challenges of ensuring tight controls and carefully managed key life-cycles when so many vendors are involved.

Additionally, these cobbled solutions can also suffer from poor power efficiency, network reliability, and sensor accuracy. Piecing together a reliable network of devices requires extensive testing in real-world environments and several iterative improvements, taking inordinate amounts of time to achieve a desirable quality of service, at scale. If it takes too long, this may cause projects to fail.

Skills and experience gap in the industry

Most businesses now have teams experimenting with IoT, yet very few of those teams have experience with large-scale, geographically distributed IoT deployments. This can result in unexpected costs, risks and delays in real enterprise scale projects.

A PLATFORM FOR ENTERPRISE IoT

Fybr has deployed multiple live IoT deployments to monitor city infrastructure, managed thousands of devices, handled billions of events, and proven reliability in extreme weather and harsh urban conditions.

Fybr is an integrated stack of technologies that reliably & efficiently connect physical assets and infrastructure to make them monitorable and controllable by intelligent, data-driven algorithms.

For enterprises, orchestrating their digital transformation, we provide a proven platform-as-a-service foundation that is tightly integrated—from machine to cloud—to design, build, deploy and operate large-scale, enterprise-grade IoT solutions.

Proven at scale

The Fybr platform has proven its ability to deliver accurate, reliable, real-time data across thousands of devices in some of the harshest urban environments like Washington D.C, San Francisco[8], Montreal, and Dallas; in university campuses like Texas A&M; and recently in truck rest stops along US Highways.

Deploying a network of tens of thousands of geographically distributed, ultra-low-power, wireless devices in a complex urban environment can present many real-world challenges, many of which we have incorporated into our current system:

- Operating in Montreal's -27°C winters, we learned how to maintain battery reliability and efficiency in extreme weather conditions.
- Operating in radio noise-prone Washington DC and electromagnetic interference prone San Francisco, we perfected reliable, efficient, low-latency, and secure delivery of messages to and from devices in harsh, evolving urban settings.
- Rapidly iterating with our customers in these early deployments, the Fybr Platform is highly tuned for safe, reliable and power efficient Over-The-Air updates to firmware, configuration and algorithms operating in the low-power edge of the network.
- To achieve sensing accuracy levels unattainable by individual edge devices with extremely limited computational ability and power constraints, we implemented a server-side machine learning infrastructure that acts as a learning center for edge devices. Models and configuration can be learned on the server and applied at the edge.

Proven at scale *(cont.)*

- To further improve sensing accuracy, noise filtering, and for certain use-cases like traffic monitoring to be viable, we developed real-time collaboration techniques that allow multiple edge devices to collaborate on decisions.

- For high security, we've implemented best practices, secure network protocols, anomaly detection algorithms, and tightly controlled processes into our system that carefully manage the entire life-cycle of devices and their keys from manufacturing to recycling and enable a reliable, encrypted—yet power efficient—network.

- Installing tens of thousands of devices while navigating city permits and permissions, our field teams have highly optimized installation, configuration, and testing processes. For example, installing Fybr's parking sensors in roadbeds takes a team of three people less than five minutes per sensor.

- Integrating with various city and partner systems for bi-directionally communicating real-time events, payments, metadata, business rules, and data models, we implemented a flexible, modern integration layer with RESTful and Streaming APIs.

End-to-End IoT System

Fybr is a comprehensive, modern framework that spans from edge devices to cloud servers and enables rapid development for a variety of industrial IoT use cases.

The foundational components of the Fybr Platform are:

Fybr Engine

An elastic cloud with a distributed stream processing core, a device data lake, a real-time asset knowledge graph and secure device life cycle management; the Fybr Engine provides highly customizable, machine learning empowered, digital twins with streaming decision pipelines to help integrate physical devices into your enterprise business processes. Fybr Engine also provides RESTful and Streaming Application Programming Interfaces (APIs) along with pluggable enterprise integration modules to cut across silos and enables integration between enterprise systems and connected devices.

Fybr Network

A highly optimized, secure and reliable physical network for low-power wireless or wired devices, the Fybr Network provides a fault-tolerant, battery efficient, low-latency, high-throughput, encrypted, bi-directional communication layer that can simultaneously host multiple IoT applications. The Fybr Network works with Fybr Engine to provide safe over-the-air upgrades, granular configuration management, security monitoring and reliable delivery of device messages.

FybrLynk™

A wireless hardware module that is compatible with thousands of existing off-the-shelf peripheral sensors, the FybrLynk provides hardware-based cryptography with encrypted key storage and comes in a drop-in form factor for easy PCB design and manufacturing. The FybrLynk comes ready-to-connect with the Fybr Network—providing the ability to field thousands of devices with a low-power wireless network that has been proven to be reliable and battery efficient in harsh, interference prone city-scale deployments.

Fybr Device OS

FybrLynk modules come installed with the Fybr Device Operating System. The Device OS has baked-in Fybr Network protocols and brings with it the reliability, fault-tolerance, security and power efficiency of the Fybr Network. The Fybr Device OS also provides a safe sandbox environment for programming edge devices with customer business logic—improving the speed of iteration and innovation of IoT solutions by significantly reducing the risk of accidentally pushing bad firmware updates that may destroy your entire network.

End-to-End IoT System *(cont.)*

Fybr ToolChain

Fybr provides a comprehensive set of tools to develop, integrate and operate IoT solutions—helping businesses run better.

The Fybr Toolchain includes an operations dashboard designed to help install, configure, and monitor devices; APIs and integration tools to integrate with enterprise services; visual application development tools to help program edge devices and their digital twins with business logic; and a hardware development kit to build FybrLynk based devices.

The Fybr Engine, Network, Lynk, OS, and ToolChain were designed to form a tightly integrated technology that enables rapid development of custom solutions on a proven foundation to minimize time-to-market and the risks of building on a piecemeal stack while maximizing return on investment and system reliability.

Machine Learning and Edge Computing

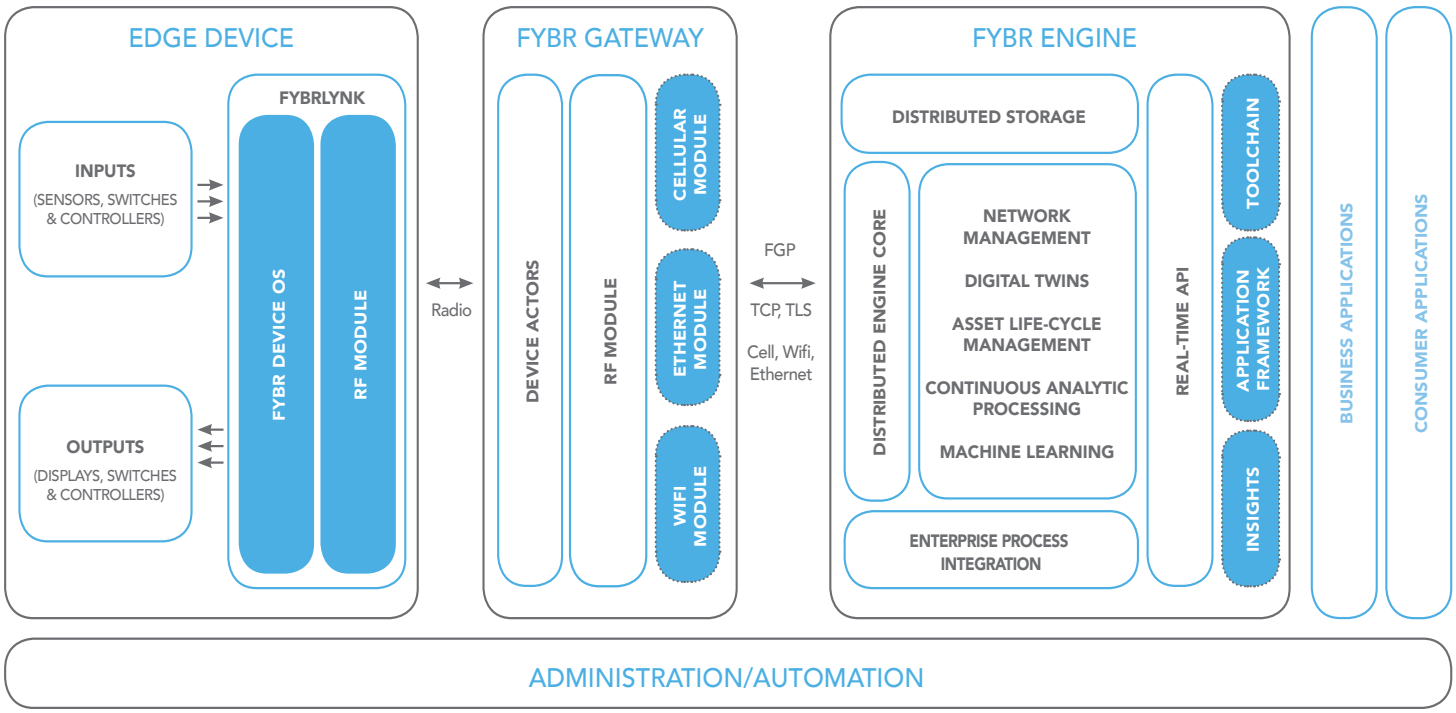
In most IoT applications, the only way to accurately sense a physical event or condition change is to use algorithms that can be individually tuned to the surroundings of a particular device in a network that may contain thousands of similar devices. Statistical learning algorithms can be a powerful tool for this purpose.

Low-power edge devices, however, don't normally have the storage or computational capacity needed to run machine learning algorithms. An individual device also does not have visibility into the data from several similar proximate devices which greatly aid statistical algorithms.

A trip to the cloud servers for every decision can be detrimental to battery life while introducing latency. In an emergency response—like stopping a car, closing a valve, sounding an alarm, or breaking a circuit—waiting for a server roundtrip isn't feasible.

Fybr's Mississippi streaming layer and the Fybr Data Lake deployed along with Hadoop, Flink, Titan and OpenTSDB enable a robust analytics and machine learning environment that can look at historical data across devices to learn models that may then be pushed to edge devices.

Reliable and battery efficient Over-The-Air updates provided by the Fybr Network and FybrLynk along with the safe sandbox provided by Fybr Device OS enable the Fybr Engine to analyze device data, learn models, and then safely send those models to devices for execution on the edge.



Machine Learning and Edge Computing *(cont.)*

The tightly integrated Fybr platform stack turns our servers into a learning center for the edge device network. This is a unique capability of the Fybr architecture.

Edge devices can—independently, accurately, quickly, and with minimal power—sense, infer and act on their environment.

At the same time, the Fybr Engine can consider historical data, enterprise business context and data across thousands of devices to learn and iterate models.

This approach guarantees sustained accuracy and reliability in urban and industrial environments that are continuously changing—all without human intervention. This type of adaptation becomes feasible and automatic with the Fybr Platform.

Also, this kind of agility is essentially impossible to achieve in piecemeal solutions. Sensors, Firmware, Networks, and Cloud Services created by multiple vendors and brought together by a system integrator cannot easily reach the level of coordination needed to put together applications that leverage machine learning to improve the accuracy of the system while working inside power constraints and latency requirements of cutting-edge IoT applications.

Digital Twins

Digital Twins can deliver tremendous value to IoT applications. Gartner listed Digital Twins as part of their Top 10 Strategic Technology Trends for 2017[9].

"Digital twins of physical assets combined with digital representations of facilities and environments as well as people, businesses and processes will enable an increasingly detailed digital representation of the real world for simulation, analysis, and control."

Mississippi, built on Erlang, provides light-weight parallel actors that represent each physical device, asset, service, and user inside the Fybr Engine. This approach creates flexible Digital Twins[10] that can concurrently communicate and collaborate with each other inside the engine.

The digital twins of each asset can communicate, in real time, with the twins of other assets—enabling physical assets to communicate and coordinate actions, making real-time collaboration between devices that are physically far apart feasible. There are many examples: traffic sensors on a highway can inform streetlights that may be miles ahead; parking sensors may inform autonomous vehicles where to find parking at their destination; temperature, water pressure, radiation or air quality sensors may alert emergency response drones and teams when it is safe to approach.

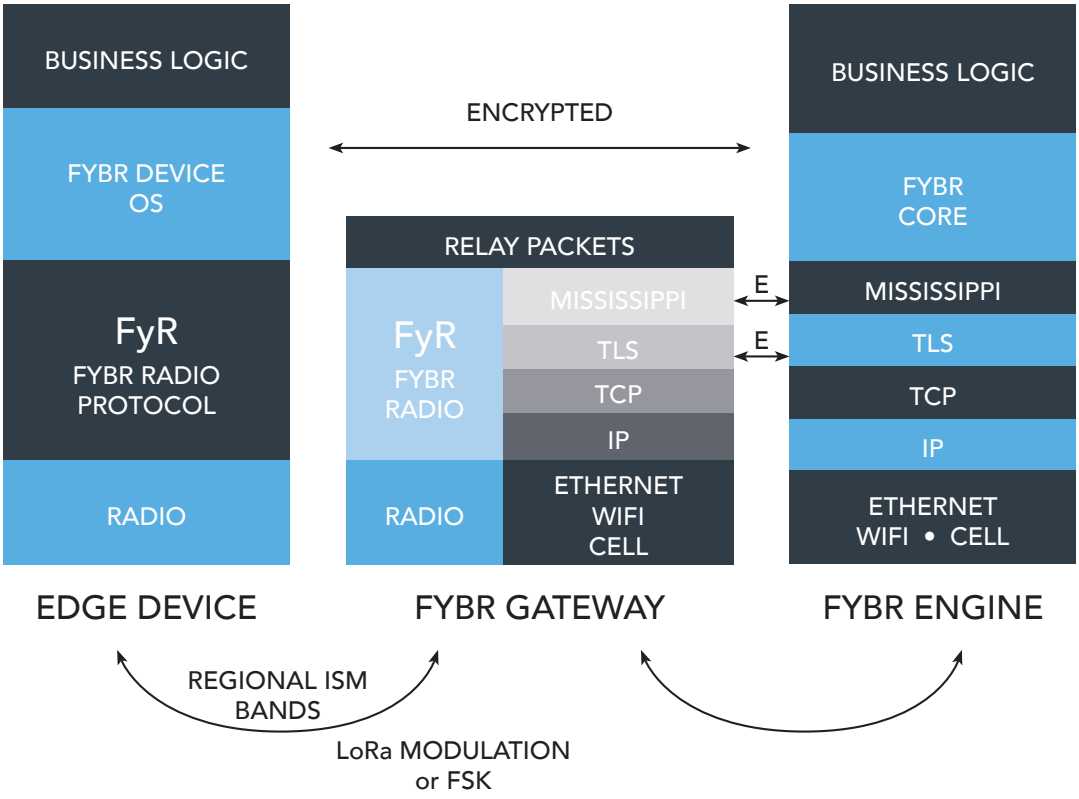
Designed for ultra-low power, agility, security and reliability

The Fybr Platform is designed to help enterprises implement secure and reliable IoT applications—particularly in use cases where it may not be feasible to provide continuous line power.

From our experience deploying large-scale IoT systems in various urban environments, we've learned that to successfully maneuver the tricky trade-offs between reliability and power efficiency, all the moving parts of such systems must work together seamlessly.

Agility and enterprise customization in IoT systems is similarly difficult to achieve.

Various, tightly integrated components of the Fybr Platform work together to deliver on these difficult enterprise goals.



Highly Reliable, Fault-Tolerant Device Network

The Fybr Network connects physical edge devices with the Fybr Engine.

A typical implementation is composed of Edge Devices communicating with Fybr Gateways, which then communicate with the Fybr Engine running in a public or enterprise cloud.

Edge Devices may be plugged into expansion ports on a gateway or may be wirelessly communicating with gateways over radio via the FybrLynk. Messages can flow in both directions, from devices to gateway to engine or from engine to gateway to devices.

The wireless radio network is a star-of-stars topology, Low-Power Wide-Area Network (LPWAN) based on the LoRa standard. Fybr gateways support radio communication with devices using the specialized Fybr Radio Protocol.

The Fybr Protocol performs significantly better in scenarios that have strict latency and throughput requirements while keeping power use to a minimum.

If the edge devices on a wireless network are FybrLynk-based devices with Fybr Device OS which has built-in support for the Fybr Radio Protocol, very powerful features are made possible by this integration.

The Fybr Radio Protocol, working with the Fybr Engine, supports highly efficient and reliable Over-The-Air updates. Edge devices can also fail-over from one gateway to another which is of particular importance in maintaining reliability in urban and industrial environments where obstructions and noise are common.

Edge devices also have gateway affinity which improves power efficiency while still supporting fail-overs. The Fybr Radio Protocol supports AES128 encrypted messaging and includes measures like checksums, nonces, and message integrity codes to detect and mitigate device tampering and man-in-the-middle attacks.

Most importantly the Fybr Radio Protocol has been proven to be reliable and power efficient in dense, noise-affected urban networks.

A STRATEGIC PARTNER

Digital Enterprises require a new kind of IT foundation, one that enables business systems and processes to reliably sense, infer, and act on the physical world. Progressive organizations recognize that the Internet of Things is strategically critical to achieving cost efficiency and consumer centricity.

Although many companies have already begun their exploration of how to leverage IoT within their industry, enterprise-wide deployments will require a cautious approach to ensure scalability, interoperability, security, and project success. Large scale IoT projects are for most companies uncharted territory that present a plethora of novel, complex challenges. Customers can now use the Fybr Platform to build on mature, tested, core capabilities, and draw on the lessons Fybr has learned from deploying at scale in harsh urban environments.

Carefully crafted by a team that has deep expertise in engineering wireless networks, industrial hardware, embedded software and big data systems, the Fybr Platform, provides companies with a battle-tested foundation to rapidly, reliably, and efficiently connect infrastructure and equipment, making them monitorable and controllable by intelligent, data-driven algorithms. Fybr began with a known business issue—parking availability—with a high-value known return on investment (ROI). Since then, we have expanded our deployable smart city solutions for parking, transportation, lighting, weather and air quality, and water monitoring/management.

Along with a proven, tightly-integrated, machine-to-cloud technology core, Fybr offers a comprehensive suite of vertical solutions to help our customers move ahead of their competition. Our turnkey offerings were designed in close collaboration with industry-leading partners and experts to provide templates for success that our clients can quickly adopt and take to market. We also provide support and services necessary to help customers benefit from Fybr's stack of technologies and tools.

FYBR PARKING SOLUTION

- Fybr Platform
- Fybr Parking Sensor III
- Fybr Gateway III
- Parking Genius™ Public Wayfinding App
- Fybr Enforce™ - Enforcement Wayfinding, and Ticketing
- Fybr Parking Insights™ - Real Time and Historical Data Analytics
- API Layer For User Engagement

FYBR SMART CITY SOLUTION

- Fybr Platform, Applications and Mobile Apps
- Mobility, Transportation, and Parking Monitoring and Control
- Lighting Monitoring and Control
- Storm/Sewage Water Monitoring and Control
- Public Safety and Security Monitoring and Control
- Environmental Monitoring
- API Layer For User Engagement

FYBR ASSET MANAGEMENT SOLUTION

- Fybr Platform
- RF Propagation Analysis
- System Design Services
- RF-Enabled Asset Tags
- RF Base Station

Advantages of the Fybr IoT Platform

- Our solution is complete and ready to deploy, fully integrated, turnkey for our chosen markets, and provided with high-touch customer service and support
- Fybr is focused on several areas that have shown the potential for high return on investment, including transportation/parking, water management for both municipalities and agriculture, and lighting for smart cities
- Fybr parking sensors and pay-by-phone apps can often replace on-street meters, kiosks, and hardware— significantly reducing capital costs.
- A fully managed smart parking system can be installed and maintained for less than 50 cents per space per day at today's pricing
- A fully managed smart irrigation solution can be installed for similarly attractive economics

Once the initial solution is in place, other low data-rate, low-power, wireless solutions can be added to the network at nominal costs enhancing the data set and further improving the analytics capability. In addition to Smart Cities, water monitoring and management for the agricultural industry (Fybr Smart Farm) is a high-priority vertical.

70%

With 70% of the World's water supply[11] **used for agriculture**, and an anticipated 20% increase in agricultural water demand by 2050, finding ways to more efficiently manage agricultural water use is a necessity.

We believe our platform can deliver more efficient and intelligent use of water—reducing overall water consumption within the agricultural industry.

In preliminary experiments, IoT systems designed to monitor soil conditions reduced water usage by as much as 75% over traditional irrigation methods.[12]

Fybr's water management platform begins in-ground testing in the spring of 2017 with major growing operations in California's San Joaquin—connecting sensors and irrigation controls vital to farm management—creating an integrated smart farm solution.

FYBR'S GO-TO-MARKET APPROACHES

OFFERING	ELEMENTS	FUNCTIONS	USE CASES
Edge Device	FybrLynk, Parking Sensor, Roadway Sensor, Lighting Control, Gateway, etc.	Hardware, Firmware, Development tools, Device Security	Enterprise or start-up buyer wanting to build their own full stack solution using existing hardware and firmware tools
Device as a Service	All of the above, plus Network, Stream and Device Lifecycle Mgmt.	All of the above, plus Orchestration, Monitoring, Quality of Service, Security	Enterprise, start-up or platform user/company wanting to manage data and information, but not devices or network
Platform as a Service	All of the above, plus Cloud-hosted Fybr Engine, Fybr Insights, Integration tools, System UI, and API Layer	All of the above, plus Customizable Data Model & Business Logic, Enterprise and Third Party Data Integration, Real Time Stream Processing Engine, Analytics and Machine Learning Engine, Application Building Blocks, System Management	Enterprise or start-up focused on data and information services, machine learning, or application development or wanting to rapidly design and test an idea or product/service
Solution/Software as a Service	All of the above, plus use case specific device configurations, dashboards and apps	Turnkey hardware, network, cloud, software, user applications—ready to be installed and customized to local requirements	Enterprise or start-up, system integrator, or service delivery company focused on time to market, scalability, & reliability
Build-Operate-Transfer or Design-Build-Operate	All of the above, plus Strategy and Engineering Support & Operations Mgmt.	Using Fybr Platform and tools, Fybr will engage in the strategy, design, implementation and operational support of custom solutions	Governments, start-ups, carve-outs, and large scale infrastructure projects looking to take advantage of proven digital concepts and capabilities

IP Strategy & Patent Portfolio

Fybr currently owns 13 granted US patents, seven pending US patent applications, and 52 pending foreign patent applications.

Fybr has also documented several software inventions that were filed in Q4 of 2016 related to the Fybr Engine and Fybr's enterprise and mobile apps. Fybr is currently executing a "Hybrid Barrier to Entry and Commercialization" intellectual property strategy in which we are filing for patent protection for current products and technologies as well as products, technologies, and services under development.

Fybr has also added the Middle East to its filing strategy, which currently includes the following countries: United States, Europe, China, Canada, Australia, India, Brazil, Mexico, Argentina, Japan, Singapore, Hong Kong, and Malaysia.

As our new patent applications become issued patents over the next two years, adequate coverage to exclude certain competitors from selling similar products will give Fybr a greater marketplace advantage.

Our dedication to operational excellence and client success is a core company value at Fybr.

Delivering proven solutions, and being a partner, as opposed to a vendor, is how we can deliver additional value to our customers—ultimately helping them to gain a strategic advantage in the marketplace.

However, we have many loftier goals at Fybr. We want to deliver technology that not only makes businesses better but technologies that can improve the lives of people—making communities more vibrant, better places to live and work. Whether it's by reducing traffic congestion, or reducing water consumption in drought affected areas, Fybr can make a difference.

fybr

CONTACTS & REFERENCES

Bob Glatz
Chief Executive Officer
+1 636.730.3111 x100
bglatz@fybr.com

Bret Beringer
Chief Engineering Officer
+1 636.730.3111 x100
bberinger@fybr.com

1 Digital Transformation: A roadmap for billion-dollar organizations

2 Industry 4.0: Building the digital enterprise

3 Disruptive technologies: Advances that will transform life, business, and the global economy

4 Digital Transformation Initiative – unlocking $100 trillion for business and society

5 Fifty Examples of Digital Business

6 With Internet Of Things And Big Data, 92% Of Everything We Do Will Be In The Cloud

7 Strategic Principles for Securing the Internet of Things

8 SFPark

9 Gartner's Top 10 Strategic Technology Trends for 2017

10 What Is Digital Twin Technology - And Why Is It So Important?

11 United Nations - Water For Food

12 IoT enables avocado farmer to recover investment in connected hardware in less than six months by slashing water consumption

13 Fybr's Next-Gen City Operations Platform: An Embedded Collaborative Learning Edge Architecture