TCS Connected Universe Platform and beyond

Internet of Things – Opportunities Unlimited

Internet of Things (IoT) is now one of the main pillars of the digitization revolution. Globally, IoT is spreading far and wide in a large variety of applications for end consumers, businesses, government and citizens at large. Leading think tanks have appreciated the importance of IoT and have urged policy makers and business leaders to take a long term and strategic view of IoT.
Leading analysts, technology companies and consultants have estimated the IoT market in terms of number of connected devices, investments, market size for products and services around IoT, growth rate as well as the economic impact of IoT. The numbers though differing widely from one forecast to other, are truly staggering.

Some of the largest spends on IoT comes from verticals such as manufacturing, transportation and logistics, retail and CPG, utilities, and automotive. Key applications in these domains include asset management, inventory managed, supply chain management, facility and energy management, fleet management, telematics, and smart grids.

Following are the IoT market predictions made by some of the market leaders:

IoT installed base will be 30.7 billion devices in 2020 and **75.4 billion** in 2025 – IHS

Total IoT market size will grow to **$3.7B** in 2020 – McKinsey

1. Internet of Things: The Complete Reimaginative Force
http://sites.tcs.com/internet-of-things/
2. Roundup Of Internet Of Things Forecasts And Market Estimates, 2016
https://www.forbes.com/sites/louiscolumbus/2016/11/27/roundup-of-internet-of-things-forecasts-and-market-estimates-2016/#b2c96ec292d5

Organizations that are already using, or planning to use Digital Technologies -Social, Mobile, Cloud, Analytics, and now are also considering adopting IoT.
Examples of potential customer organizations are as follows:

VERTICAL / SECTOR	CUSTOMER TYPE(S)	SAMPLE USE CASES
Manufacturing	Manufacturer of large industrial equipment	▪ Remote asset monitoring and installed base management ▪ Factory-of-the-Future ▪ Supply chain visibility ▪ PLM (MRO and product performance monitoring)
Healthcare	Health insurance providers	▪ Customer engagement via lifestyle management ▪ Chronic disease management
Insurance	▪ Auto insurance ▪ General insurance	▪ Pay-as-you-go insurance ▪ Driver behavior based insurance ▪ Property damage prevention
High tech	▪ Semiconductor manufacturing equipment provider Advanced ▪ instrumentation systems manufacturer	▪ Installed base management Remote monitoring and ▪ servicing of products at customer sites
Retail	▪ General merchandize ▪ Quick service restaurants	▪ Energy management ▪ Kitchen operations optimization
Government	▪ Housing development boards ▪ Municipal services	Smart cities ▪ Smart lighting ▪ Environmental monitoring ▪ Waste management ▪ Asset management

VERTICAL / SECTOR	CUSTOMER TYPE(S)	SAMPLE USE CASES
Utilities	▪ Electricity ▪ Water	▪ Smart Grids ▪ Smart Metering ▪ Network Optimization
Energy & Resources	Upstream Oil and Gas	▪ Remote operations management ▪ Remote asset monitoring
Transportation	▪ Railroads ▪ Fleet operators	▪ Remote asset monitoring ▪ Fleet management and optimization
Telecom	Telecom service providers	▪ M2M platforms ▪ Value added services based on M2M

While opportunities are immense, the challenges of a successful IoT application are non-trivial. Keeping in sight of the needs of all stakeholders, building and deploying IoT based systems and operating them optimally requires considerable expertise in architecture, engineering and operations.

This paper presents the TCS Connected Universe Platform, a key enabler for quickly building and deploying large scale, high performance and secured IoT applications.

TCS IoT Offerings

TCS IoT related offerings and services covers strategy, implementation and support aspects.

Strategy offerings include business case development, use case definition, RoI analysis, ecosystem development and high-level architecture definition. Implementation services include IT/OT integration, device integration, enterprise integration, data management, analytics and application development, IoT platforms, middleware and related services including the TCS Connected Universe Platform.

Support services include
DevOps services, monitoring and management, test and validation, NOC and application support.

TCS Connected Universe Platform
http://www.tcs.com/about/research/Pages/TCS-Connected-Universe-Platform.aspx

TCS Connected Universe Platform – Building Eco-Systems and Bridging Market Gaps

IoT application developers need a functionally rich set of services for device management, data management, real-time stream processing, and support for batch oriented analytics and application management. Developers need to leverage an ecosystem consisting of Generic PaaS for infrastructure and telco clouds for SIM/connectivity management.

TCS Connected Universe Platform addresses a unique gap in the market that is not served by either generic PaaS clouds, or device management clouds or M2M platforms provided by telcos.

Generic PaaS platforms such as AWS or Azure, while providing excellent support for general purpose software stacks, are not adequate with respect to IoT specific support. Device clouds that provide device management services are very specialized for specific devices and lack the support needed for customer IoT data processing, analytics and application development. Telco M2M platform on the other hand are designed essentially for basic cellular connectivity management and SIM and lack data, device and application management.

Based on requirements, the application must be integrated with various device clouds, M2M platforms, and PaaS cloud platforms. Also, vendor lock-in and use of proprietary interfaces must be avoided.

Following figure shows how the TCS Connected Universe Platform bridges market gaps with pre-built support for industry standard protocols, built on micro services framework.

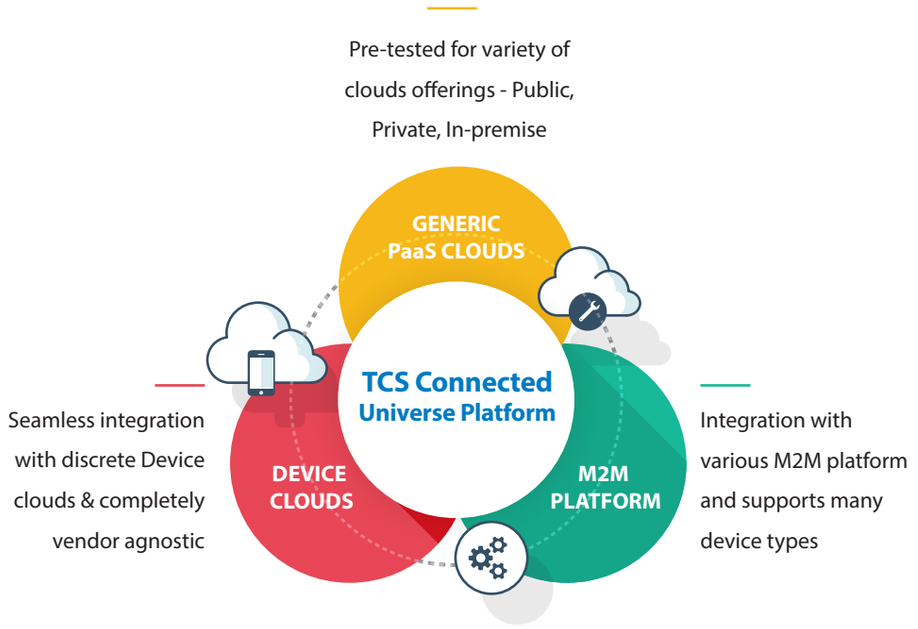


Figure 1:
TCS Connected Universe Platform: Building Ecosystem and Bridging Market Gaps

TCS Connected Universe Platform Addresses Challenges

TCS Connected Universe Platform addresses the major engineering and deployment challenges faced during the build, deploy, and manage lifecycle phases of an IoT application.

Build

One of the main design goals of TCS Connected Universe Platform has been to reduce the time, effort and expertise needed to create industrial grade, robust, scalable and secure IoT applications.

In any IoT project, the first step is typically creating the necessary device integration and data acquisition layer since numerous legacy instrumentation and automation systems may need to be integrated. As part of TCS Connected Universe Platform, a large collection of pre-built, integrated, and tested connectivity protocols are provided. Device side components of the platform have been tested on many popular embedded platforms and gateway devices. Various third party device clouds and M2 connectivity management platforms may also be used optionally along with TCS Connected Universe Platform components to create a custom solution.

It is important that the platform provides the flexibility to support evolving devices and sensors as they become available for general use. TCS Connected Universe Platform uses a common standards based meta-model for defining sensors, observations, and real-world entities ("things"). Using this meta-model, virtual sensors, devices, and observations can be modelled. Sensor observations can be simple time series data or even unstructured data such as images or blobs.

IoT applications also need locational intelligence capabilities. Real world entities such as assets, places, buildings, infrastructure, and even people have geometric properties along with location attributes with respect to both global (Example: latitude /longitude) as well as local reference systems. Sensors, both fixed and mobile, have locational data and sensor observations can also be tagged with location data. IoT applications therefore need strong spatial query and filtering capabilities and TCS Connected Universe Platform provides such capabilities out of the box.

he platform provides a foundation of generic services using which the 'build' functionality can be realized for a large class of IoT applications. Services are exposed as Application Programming Interfaces (APIs) and they abstract the inherent complexities of creating applications that have the requisite engineering properties.

Some of the most common functional requirements in any IoT application are as follows:

- Data acquisition from sensors and devices
- Provisioning, remote monitoring and managing devices – including over the air configuration and updates
- Processing streaming sensor data and events - including real-time analytics, complex event processing, mining, summarization, and enrichment of data streams
- Data management and query processing on stored sensor observations
- Visualization

Details of the platform components are described in the TCS Connected Universe Platform Overview section.

Some of the most important engineering properties needed for IoT applications are as follows::

- **Scalability** – IoT applications should provide consistent performance even as the number of devices, frequency of data collection, device data payload size, and number of end users increase over a period of time. In an IoT application, the number of devices can potentially be in millions.
- **Security** – IoT applications must ensure that device endpoints, the communication channels as well as backend software components meet necessary authentication, authorization, data integrity, confidentiality, and privacy requirements
- **Quality of service** – IoT applications must provide the necessary quality of service in terms of system availability, device data availability, data quality, and latency
- **Robustness and self-healing** – the system must be able to run

The Industrial Internet Reference Architecture, published by the Industrial Internet Consortium discusses these non-functional requirements in details [https://www.iiconsortium.org/IIRA.htm]. TCS Connected Universe Platform components have been designed with these requirements in mind.

Deploy

Every IoT application is unique in its own way and therefore needs to be composed using a unique combination of varied functional blocks. Components need to be deployed on edge devices as well as on servers in the data centre or cloud.
Key requirements to be met are:

- Deploy a fit-for-purpose configuration of various components. Remove all redundancies since unnecessary components waste resources and are additional points of failure and security vulnerabilities
- Automate the deployment via recipe driven scripts
- Automatically load balance and deploy additional service instances based on load

4. Build a Scalable Platform for High-Performance IoT Applications
http://www.tcs.com/SiteCollectionDocuments/About%20TCS/Scalability-IoT-Applications-0616.pdf

TCS Connected Universe Platform follows the micro-service architecture pattern. Scalability at all levels and for all components has been baked in. The 3-D scaling approach, comprising horizontal or X axis scaling, functionality driven or Y axis scaling and data driven or Z axis scaling are possible. Each component of the platform can be independently scaled at will based on demand. Refer Section on Scalability & Performance in this document for details.

It is easy to pick and choose from the collection of services needed for a given application and deploy optimally. Deployment automation scripts can deploy TCS Connected Universe Platform on single physical machines, virtual machines on large clusters of virtual machines or container clusters as needed. The architecture enables consistent performance as the number of devices and data volumes scale.

Manage

Once an IoT application is deployed, it needs to be operated and managed for years to come.

The infrastructure, application and software, at the edge locations as well as the data center/cloud, must be operated and managed in a way that guarantees high availability and security. Some of the key requirements are:

- Support for device provisioning and device management
- Infrastructure, network, and services monitoring
- Health of the platform and network connections
- Health of connected devices and diagnostics
- Quality of device originated data as well as the availability of data needs to be monitored
- Authentication and fine grained access control of platform services along with dynamic management at run time
- Monitoring all logs including security logs and events and triggering auto-remediation as appropriate

TCS Connected Universe Platform device management services, over the air upgrade, and API gateway helps address some of these critical requirements.

TCS Connected Universe Platform Overview

TCS Connected Universe Platform can be considered to be a set of micro-services that run on the cloud and a set of device side software components. The figure below shows the main components of the platform and how they are layered.

Server/cloud side components are grouped into the sensor and device layer, real-time processing layer and stored data processing layer. The components in each layer are as follows –

- Sensor and device layer – consists of Device Management and Sensor Data Management services
- Real-time processing layer – consists of Message Routing, Complex Event Processing, and Action Services
- Stored data processing layer – Task Services, Asset Management, and Data Explorer and Visualization

All services are exposed as API and access to services are controlled via an API Gateway.

These components are described in detail in the following sections.

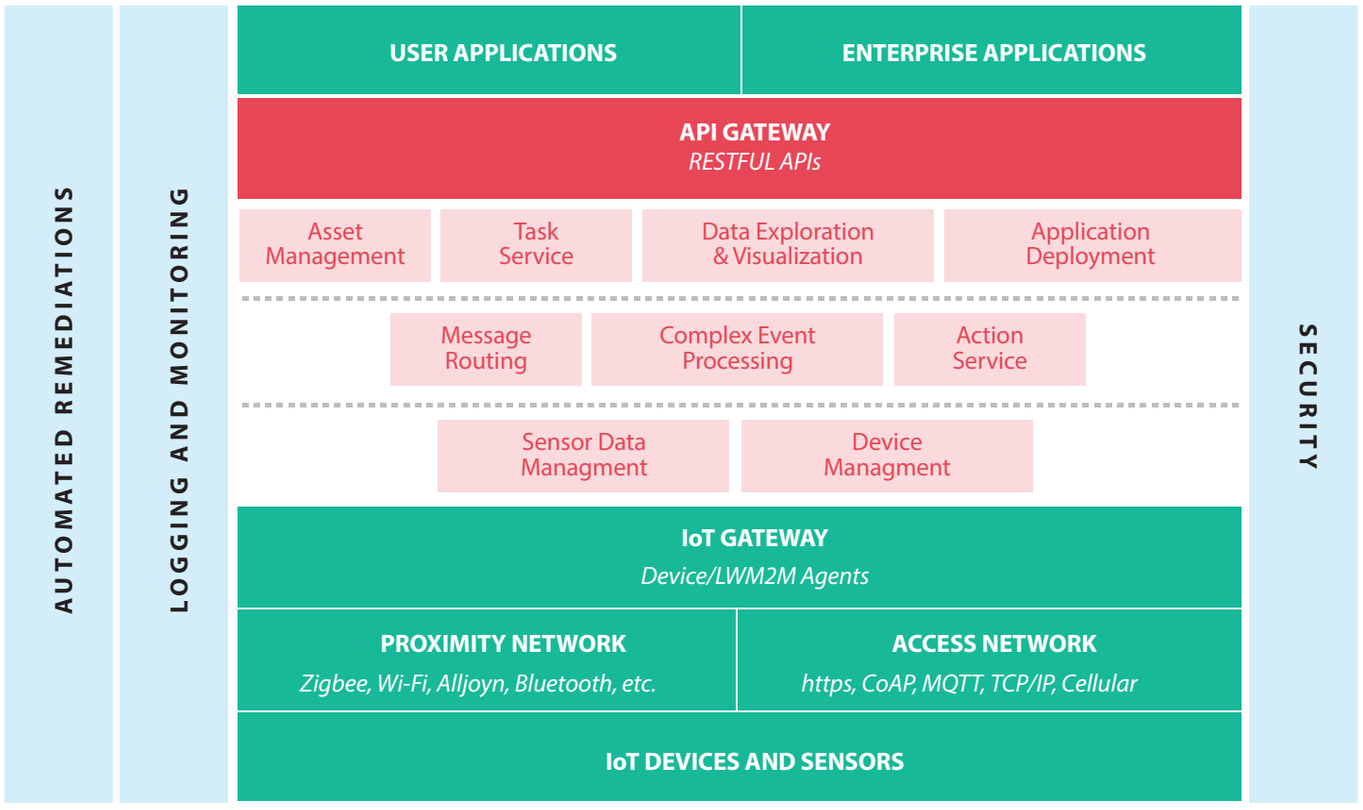


Figure 2:
TCS Connected Universe Platform: Architecture

TCS Connected Universe Platform services provide rich set of business functionalities as shown below:

Figure 3:
TCS Connected Universe Platform – Features and Functionalities

Device Management

TCS Connected Universe Platform Device Management (DM) service allows remote monitoring and management of edge devices and gateways. It enables remote monitoring of devices and sensors, observes devices and their resources, sends commands to devices and upgrades them over the air. Device Management is used for setting parameters, querying, capturing sensor data, troubleshooting, OTA upgrade and so on.

The platform DM is based on Open Mobile Alliance's (OMA) Lightweight M2M standard which defines a Client-Server based framework. The DM services running on the cloud behaves as the LWM2M server and a device agent running on the device acts as a client. LWM2M uses CoAP as an underlying lightweight transport protocol optimized for use by resource constrained devices with very little network overhead. It follows a RESTful way of managing and monitoring devices. All device side functional and non-functional components are modelled as objects with resources and each of these resources can be accesses via a URL. All device management functions are realized as GET/PUT or POST operations on these resources.

TCS Connected Universe Platform Device Agents

Device agents are pre-built customizable software modules for edge IoT devices developed in C and Java that enable LWM2M based device management. Device agents allow all device side resources to be queried, updated or subscribed to. When resources are subscribed to, the agent automatically notifies of any changes in values. Thus real-time event driven actions can be taken when device side data such as sensor observations change. The LWM2M standard defines certain mandatory resources to be present. In addition, based on application need, custom resources can be easily added. TCS Connected Universe Platform device agents are robust against communication failures and reconnections and are able to encrypt data via the DTLS protocol.

Device agents also enable the bootstrapping process by which agents securely discover a DM server and securely register themselves to the server. The device agent itself can be securely upgraded using the platform's OTA upgrade service.

Device Connector SDK

The platform also provides software libraries developed in C and Java that encapsulate calls to TCS Connected Universe Platform Sensor Observation Services APIs. These libraries enable all device side applications to inject data to the platform over HTTP(S) or MQTT(S) protocols. These libraries are available for various popular embedded system platforms and architectures.

Network Protocols Libraries

Devices may be connected directly or indirectly. Directly connected devices may connect to the Device Management (DM) server using long haul connections such as Wi-Fi, GPRS and Ethernet. Indirectly connected devices/sensors connect through directly connected gateways over Bluetooth, ZigBee, WLAN, USB or any other short haul protocol. Protocols such as OPC-UA, Modbus-TCP and Continua, are supported on the platform.

A highly scalable and secure MQTT gateway is available that allows any device to inject sensor observations and messages via MQTT transport. This gateway integrates with TCS Connected Universe Platform Message Routing and CEP services and enables processed, filtered, and aggregated MQTT data to be passed on to any desired application endpoint.

The table below is a representative list of some devices and network protocols supported.

DEVICE CONNECTORS AND PROTOCOLS	
Device connectors	HTTP/HTTPS, COAP, MQTT
Network protocols	HTTP(S), MQTT, CoAP, TCP/IP, UDP, LWM2M
Embedded system support	Arduino, Raspberry Pi mBed and ARM Cortex based systems from TI, Freescale, Qualcomm Intel Atom, Quark and Intel Edison based boards Embedded Linux, FreeRTOS, and Windows

Sensor Data Management

Sensor Observation Service (SOS) provides the sensor data management service functions in TCS Connected Universe Platform. It provides facility for registering new sensors to the platform, insert observations and measurements from various types of sensors and performs rich set of queries on sensor observations. This service is based on the Open Geospatial Consortiums Sensor Observation Service schema and allows virtually any type of sensor and observations to be supported. A sensor in TCS Connected Universe Platform can be a physical sensor or a soft-sensor and can be atomic or composite. A sensor can have one or more observed properties or sensor outputs and are associated with real world entities (referred to as "Features"). SOS also allows Features to be created and the relationships between different features can also be defined.

All data entities can be tagged with location information and geo-spatial queries are supported.

SOS is designed to support large volume of sensor observations and measurements from multiple applications. SOS leverages big data technologies to provide the ability to handle large number of sensors and large volume of sensor data. It uses a distributed in-memory cache to enhance query performance.

Message Routing

The Message Routing service allows application developers to create message queues and routing rules and automatically route sensor observations and events in real-time to selected message queues. It allows different sensor outputs to be grouped and filtered and lets applications take action on the groups. Routing can be done based on identity of sensors, the real-world object being observed, the property being observed, and value of the measurement.

The events can be filtered using regular expression filtering on sensor names, feature names, and observation outputs of type text. It also allows filtering based on observation values that are numbers and user defined rules with respect to maximum and minimum values. It also allows filters to be applied based on geo-coordinates of the sensor or observations as reported including geo-fencing support.

Message routing is stateless in nature and the rules are matched only on the last received message from the sensor or device. The service allows large number of rules to be matched on every incoming message and can be scaled by increasing the number of processing nodes as number of sensors and events increase.

Complex Event Processing

The Complex Event Processing (CEP) service allows more complex situations and patterns to be detected in real time. It consumes data emitted by the Message Routing service and processes that data.

The CEP service is able to fuse or join data from different sensor streams and is able to process not only the current data but also past data. Event streams are collected in user defined "windows" and conditions are checked based on aggregations done on these windows.

CEP rules as defined by the user matches data from multiple sensor streams to perform range checks, joins, and event pattern matches. Once a pattern or condition is matched, event or alarm is generated as an output.

Events to be processed are selected from incoming streams based on fields and conditions. The sensor streams can be aggregated using functions such as sum, minimum, maximum, average, and running counts. The system supports condition based filtering and mathematical transformation of event fields of a stream. Patterns of events, temporal operations, and absence of events can be filtered. It supports joining of fields based on operations on a window of time or count. Certain correlations based on condition or logical operator on multiple streams using component filtering and composition filtering is also supported. Developers can also do a real-time database lookup and join incoming streams with data. Apart from basic filtering and joining operations, there are some complex event processing operations which can be performed using this template by using the MVEL scripting language.

The processing of sensor streams is supported by an underling distributed stream processing engine that uses a large cluster of servers to distribute the event processing tasks into multiple nodes of the clusters. This engine is fault tolerant and guarantees that all events ingested are processed. The application developers get access to a rule template library. This library abstracts the technical details of the underlying stream processing engines and exposes the entire set of functionality in form a RESTful API.

Action Services

Action services allow users to execute or invoke different types of action when certain events or conditions are detected. Notifications, alerts, and alarms can be generated and delivered using push notification, email, SMS and so on. Application developers can define any custom action type and invoke external REST web-service call (HTTP Post and GET method). Also, action services allow RESTful APIs of other TCS Connected Universe Platform services to be invoked. Some other actions supported are dumping to external database or push notification to Android or iOS phone.

Task Services

Task services is used for batch oriented data processing on historical sensor data stored and managed by external services such as TCS Connected Universe Platform SOS. IoT applications need the ability to process high volumes of data collected over a period of time and perform analysis on this data in batch mode. Typical processing involves machine learning algorithms for generating and executing analytical models.

Task Services is enables a large number of batch programs running analytics workloads to be executed in parallel on large server clusters. Developers provide the path to the program and specify the path to the data. Task Service executes these programs written in C, Java, R, Python etc. on behalf of the user. The user supplied programs are packaged into applications containers a batch processing framework is used to schedule the execution. App developers have the option of managing the schedule and specifying the number of nodes that will execute the tasks.

Asset Management

Asset service provides a “things” view and interface for IoT application developers. It allows an IoT application to be modelled as a set of assets, asset properties and rule based processing on these assets. This service can make use of APIs exposed by other TCS Connected Universe Platform services such as SOS and DM.

Asset service provides Asset Life-cycle Management by Allowing to create, update and delete assets during its lifecycle. It allows user to define various asset domains and asset types. Developers can use this service to define meta-properties of the assets and relationship between assets of different types. Property of assets include static properties, properties that are based on attached sensor observations, properties whose values can be looked up from external systems, computed property etc. User can relation between the assets.

Containment and concept based hierarchies of the assets can be built and visualized. Aggregate properties of hierarchies can be computed based on property values of individual assets.

Assets can be filtered based on hierarchy. A view is also available for asset centric details from sensor based information. Time based aggregated roll-ups at any level in asset hierarchy can also be viewed. A single dashboard presents various KPIs for asset features in hierarchical view. Assets types can be segregated with respect to different domain. The system also allows expression based scripting to derive new properties based on existing properties

Data Exploration and Visualization

TCS Connected Universe Platform Data Explorer (TDE) provides a powerful search engine, filtering, grouping and data visualization, charting and reporting facility for stored sensor data. A widget based dashboard generator can be used to create widgets, charts and dashboards. Any dataset or chart can be exported as an API / web URL and thus 3rd party applications can easily make use of data, charts and dashboards created using TDE. The Data Explorer can be used by end business users to explore and visualize IoT data.

API Gateway

All incoming API request to TCS Connected Universe Platform comes to API gateway, which validates the requests and route it to designated services. API Gateway provides Access Control and Security of API access. Additionally it does Analytics and Reporting of all API calls made. There is a facility to rate limit the API calls. API gateway supports SSL /TLS based secure communication. Additionally it supports cutting edge authentication and authorization technologies such as OAuth 2.0, JSON Web Tokens, and HMAC based integrity validation.

Application Deployment Services

It is often useful for developers to have a ready to use environment where applications can be quickly deployed for test and demonstration purposes. TCS Connected Universe Platform provides application deployment and execution environment IoT application developers to deploy and manage web applications. Web application containers, relational database access and message queues are provided as part of this service. These services allow developers to create a full functioning applications easily and quickly. The deployed applications are made accessible from the internet via a web URL.

Security

Security is now the most important concern and as we become more dependent on smart and connected devices and as machines, objects and humans communicate with each other in real-time, it is imperative that we understand the security risk and protect people's privacy and secure objects, information, networks and processes. Security is critical because of the possibility of physical harm to people and health and safety hazards in general because of weak security. For example, connected city traffic light system can be manipulated to cause traffic accidents. Also, the IoT device itself widens the attack surface available for exploitation for launching further attacks. For example, an insecure IoT device can be used as a base for launching denial of service attacks on other connected systems. Since IoT devices are large in number, the attacker can launch massive scale of such attacks. To tackle the issue of security in IOT devices, it is imperative to increase security awareness, consider security within all aspects of system design, lifecycle maintenance and management, standardization and deployment of best practices.

TCS connected universe platform offers end to end security of IoT system from 3 aspects:

1. ENDPOINT SECURITY

Ensuring Client / Device Authentication

It is necessary to authenticate both end points in an IoT communication. In TCS Connected Universe Platform, all devices communicating with cloud based services have to authenticate themselves by presenting certificates and digitally signing their messages. The servers authenticate the certificates presented and verify the signatures.

Device Hardening

The IoT device in question may run an operating system including a networking stack. IoT device hardening consists of running a minimal OS image, with all unnecessary services stopped and all unnecessary network ports disabled. Applications are run with minimal privileges

Securing Key Storage

Wherever available, TCS Connected Universe Platform device agents and connectors, make use of Trusted Platform Modules for secure storage of device private keys, secrets and root certificates used for authenticating other certificates.

Secure Bootstrapping

Secure bootstrapping allows a device to securely discover a device management server and get necessary credentials to register itself. The device connects to the bootstrap server using pre-shared secret keys using a secure channel (TLS/DTLS) and receives necessary credentials and paths to the device management server. The device management server and the device client mutually authenticate each other using pre-shared keys.

Secure Over the Air Provisioning

Over the Air (OTA) upgrade is also done over secured channel (using TLS) by mutual authentication using asymmetric key encryption. The devices validates any upgrade package received from server for its integrity, decrypts the same using server's public key prior to installation.

2. COMMUNICATION SECURITY

Ensuring Server Authentication

It is the responsibility of every TCS Connected Universe Platform client to ensure that it communicates to only trusted servers. This is ensured in the TLS / DTLS sessions when the server presents its certificates to the client devices. The clients verify the servers' certificates by authenticating them against root certificates stored within the client devices.

TCS Connected Universe Platform uses a PKI to issue, manage and revoke certificates for servers and devices/clients.

Ensuring Network Security

TCS Connected Universe Platform device connectors and device agents use standard TLS or DTLS protocols for network security. TLS is used when transport in TCP/IP and DTLS when transport is UDP/IP.

TCS Connected Universe Platform device management is based on LWM2M protocol which in turn uses DTLS for network security. TCS Connected Universe Platform device connector libraries use SSL / TLS connections to make calls to services such as Sensor Observation Services.

Additional Communication Security Mechanisms

VPN - Additional ways of reducing attack surface involves use of a VPN to create private overlay networks on top of public internet. This would ensure that the entire

IoT network is visible only to trusted sites and endpoints that have been configured with the VPN clients.

Enforce SSL - All web service calls will be over HTTPS (TLS) protocol for encrypting network traffic. Let's Encrypt CA certificate has been used to secure TCS Connected Universe Platform severs/domains using the SSL certificate.

HSTS - In addition to that HTTP Strict Transport security (HSTS) has been implemented which forces the client (Browsers) to communicate with server over HTTPS only. At server end, request re-direction has been implemented to translate any incoming HTTP requests to HTTPS.

3. PLATFORM SECURITY

API Gateway

API gateway is used for providing a security layer and rate limiting to any TCS Connected Universe Platform service access. All service calls hit the gateway first, where the API caller is authenticated and it is also checked if the particular service call has been enabled for that caller. A fine-grained access control mechanism can be enabled using TCS Connected Universe Platform API gateway.

Additionally, the API gateway checks if the rate limits associated with that caller has been exceeded or not. If limit have been exceeded, then all subsequent calls are blocked. This is quite useful in dealing with Denial –of-Service attacks by limiting the exposure of the service to the gateway itself.

Further, rogue clients can be further prevented by blacklisting certain IP addresses or by white listing only certain network addresses.

API Security

API authentication is done using a combination of API keys and authorization protocols such as OAuth2.

API keys are a set of public identities and secrets that are issued for each TCS Connected Universe Platform tenant/developer. The API key (identity) must be passed in the HTTP header of each API call. This key is used to validate the client.

Additionally, secrets are used to create key-based cryptographic message digests (HMAC) for the payload in each API call and passed as a header of each API call. These digests are verified in the server end since the secrets are shared and known to both end points (secret key never gets transmitted for API calls). Access is given to a particular API call only after validating the digest/signature at both ends.

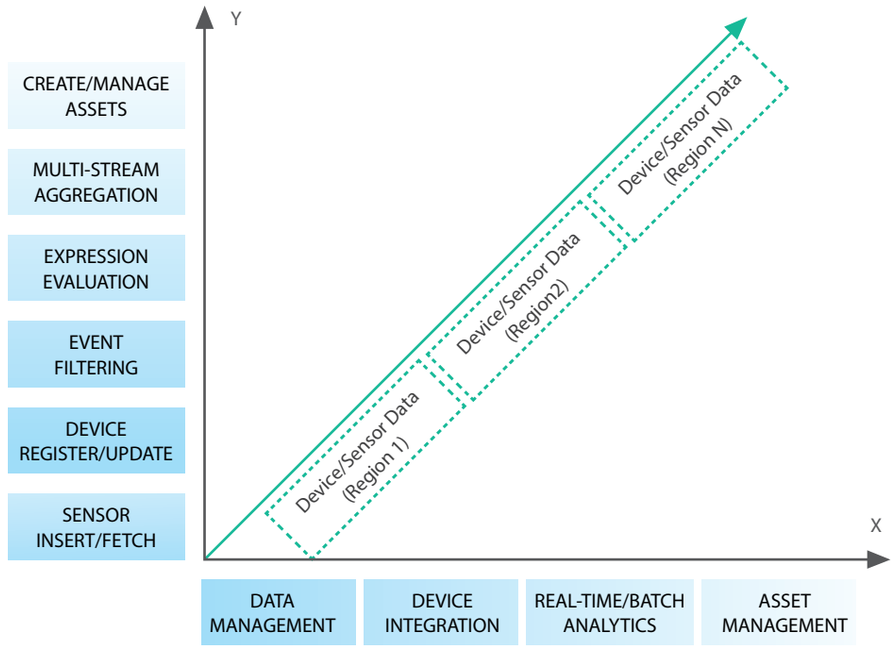
Json Web Token based authentication may also be used as additional security measure for API access.

4. MULTIFACTOR AUTHENTICATION

TCS Connected Universe Platform supports password-less SSH based authentication mechanism for all administrative user log-in. Also, another layer of security has been implemented using Time based One-Time Password (TOTP) authentication. Every time the administrator needs to access servers hosting the platform, a one-time password must be provided to establish SSH connection to the servers. This significantly reduces the probability of any unauthorized access to system even if the secured SSH keys somehow get compromised.

Scalability and Performance

TCS Connected Universe Platform is based on micro-services architecture and can scale infinitely across the following three dimensions:



X-Axis: Run multiple identical copies of application behind a load balancer (horizontal scalability)
Y-Axis: Splitting the application into multiple functions/services
Z-Axis: Run multiple identical code (Like X-axis scaling) and each copy caters to only a subset of data (Data partitioning/Sharding)
[Refer: http://microservices.io/articles/scalecube.html]

The Scale Cube
http://microservices.io/articles/scalecube.html

All TCS Connected Universe Platform services are loosely coupled micro-services that can scale independently. Its services support both scale-up and scale-out for each layer/ or component.

The platform services have also been performance tested and benchmarked and the findings substantiate the fact that the platform services are extensively scalable. The performance testing exercise has been performed on in-premise set up as well as on public cloud and corresponding metrics and system parameters captured to come up with a performance prediction models.

Reliability and Hi-availability

All TCS Connected Universe Platform services are designed in a manner that they can easily be configured to ensure reliability and high-availability. There are some components in the TCS Connected Platform Universe architecture which are inherently fault tolerant and reliable such as Hadoop, Messaging Infrastructure, and so on. Other core components can be configured as cluster to ensure a reliable platform with all services always available to use.

The layer/component wise description of HA is given below:

COMPONENT	HA AND FAULT TOLERANCE APPROACH
Data Management	TCS Connected Universe Platform uses Hadoop based Big Data storage which is inherently fault tolerant and keeps multiple replicas of data in various data nodes. The circuit breaking design approach allows storing the request and replays at later point in time in case of any service unavailability
Device Management	Request coming from devices are evenly load balanced across multiple instances of the device management server. All DM servers use a common clustered caching layer with session sharing so any server can handle device request and there is no need to retain state of each communication. Device specific data gets stored in RDBMS which is also ensures high availability by Master-Slave configuration

COMPONENT	HA AND FAULT TOLERANCE APPROACH
Message Routing	All incoming messages come to AMQP compliant message broker which is also set up in multi-node cluster to ensure the availability of messaging service and load balancing of incoming messages/observations. Actor model based cluster distribute rule processing to multiple actors for faster processing and also ensures high availability of rule processing service.
Complex Event Processing	Stream processing cluster is used for real-time stream aggregation, correlation and processing. The storm set-up is by default fault tolerant and ensure high-availability of all services. Business context related data is kept is RDBMS which is configured in Master-Slave mode to ensure zero data loss.
Actions and Alerts	Cluster based event triggering and alerting service ensures the availability of service to process action rules in load balanced fashion.
Asset Management	Multiple instances of Asset Management service run for availability and load balancing. All Asset related data is stored in RDBMS which is also set up in Master-Slave mode to keep replica of and ensures zero data loss.
API Gateway and Web Portal	All incoming requests go through the gateways so this is the most crucial component and can be single point of failure. To ensure high-availability of API GW multi-node cluster is set up and all these instances access common persistent data store. The In-Memory Data store also works a cluster mode to make the validation and routing data available all the time. The web Portal also runs on load balanced Web Container.

Platform Operations

TCS Connected Universe Platform allows various platform operations such as:

Automated Deployment and Quality Assurance: TCS Connected Universe Platform supports continuous build, automated deployment and quality assurance for entire platform or individual services. TCS Connected Universe Platform is deployed using scripts and container based technologies. The platform can be deployed in both private and public cloud. Different PaaSs provided by Cloud platform providers are also leveraged.

Monitoring and Management: TCS Connected Universe Platform allows centralized monitoring of all the infrastructure components and send necessary alerts/notification to administrator when any system parameter goes beyond normal boundary. Apart from the health of VMs/server, the platform also captures the statistics of all incoming request and provides a monitoring Interface to get the real-time details of who is accessing what.

Log Aggregation: TCS Connected Universe Platform aggregates logs from all the systems and services and stores the same in time-series in elastic storage for visualization and audit. Log management agents are installed in all the servers where individual Services run and these agents push the service level and system level logs to the Log Management Server. The system also provides a user interface to view all the logs.

Auto Recovery and self-Healing: TCS Connected Universe Platform supports auto-recovery and self-healing. Logging and monitoring services serve as input to auto-recovery module. It allows to define certain rules based on which decision can be drawn and necessary action can be initiated.

All the services and processes are checked to ensure their health in real time and if any service/process is not working, it is restarted automatically. It also takes care of OS hardening and security patch deployment/update.

Depending on the load that a particular service witnesses, it can trigger auto-scale up/down to ensure that the availability of services is not hampered with the increasing load and also un-necessary resources should be operational when load is minimal.

Success Stories

Here are some of the success stories made possible by TCS Connected Universe Platform.

Energy Management to Minimize Energy Costs and Drive Sustainable Operations for a Global IT Conglomeration

An analytics-driven energy monitoring and management solution was developed that helped optimize and enhance energy use and efficiency. The solution offered enterprise wide data integration, real-time asset performance tracking, remote monitoring for energy optimization and deviation in consumption, along with initiating corrective action by leveraging a self-learning, self-optimized machine-learning based algorithm. The machine learning based solution, monitored and optimized energy usage at the same time ensuring occupant comfort in the face of rapid business growth.

Sensor-Enabled Homes and Personalized Homecare for Senior Citizens in Singapore

A remote health and wellness monitoring solution was developed to monitor patients outside the conventional clinical environment by leveraging Information and Communications Technology (ICT) for enabling innovation in healthcare delivery. The solution included sensor-enabled homes that monitored the living environment and the daily patterns of seniors in a nonintrusive manner through fixed and mobile sensors. Real-time data was communicated to a network within the community including detecting anomalies or unusual living patterns of the respective senior so that timely intervention could be enabled. The solution made healthcare more accessible to senior citizens through early detection of problems leading to a decrease in healthcare delivery costs and increase quality of care.

Fleet Management to Provide Real-Time Travel Updates and Improve Operations for a State Transportation Corporation in India

An integrated digitized solution leveraging GPS, GIS and advanced mobile communications was developed that offers live fleet status on interactive maps, real-time updates and alerts, two-way communication as well as diagnostic information and analytical reports. The solution enabled the company to accurately track their fleet around the clock, ensure timely maintenance while at the same time providing a better customer experience to passengers through real-time updates of arrival/departure and location details.

Digitized Clinical Trial Processes for Enhanced Patient Engagement by Leading American Multinational

An IoT-enabled Advanced Drug Discovery platform was built that simplifies connectivity to Smart Medication Kits, using context-aware business data ingestion at medication intake patient touch points. The solution resulted in multiple-fold improvement in trial supply management and enhanced patient engagement and retention during a clinical trials. This further improved the operational execution of clinical trials by envisioning a patient centric digitized experience.

Smart Badges to Improve Event Based Delegate Engagement and Lead Generation by Leading American Retailer

An IoT enabled beacon based non-intrusive people tracking solution was built that provides a real-time view into how the event is unfolding. The seamless capture of delegates' activities in real time allowing for them to be analyzed for insights helped improve the events experience for delegates. In addition, better insights on attendees using advanced analytics, helped the event organizers target them through personalized, interactive, real-time communication based on interests.

Smart Badges to Improve Event Based Delegate Engagement and Lead Generation by Leading American Retailer

A connected comprehensive transportation solution was developed that integrates the telematics application with the employee bus databases to ensure employee safety with contactless authentication, provides real-time vehicle tracking, scheduling and communication, along with data on driver behavior, vehicle health and analytical reports. In addition, it restricted unauthorized passenger access while enhancing security controls and disaster management systems.

Smart Crane Operations for a Leading Port Operator

A holistic smart crane solution that established a unified reference architecture was developed which optimized the use of high value assets, increased enterprise-wide visibility on assets, enhanced operator safety and reduced costs by leveraging analytical reports. This streamlined performance by replacing manual controls and processes, monitor vast asset landscape more effectively, enabled cost savings and enhance safety measures.

Digital Kitchen Management for a Global Quick Service Restaurant Chain

An intelligent kitchen using IP-embedded network of integrated appliances was developed that would seamlessly communicate with one other through wireless communication with minimal human intervention. This enabled automated equipment start-up, on-demand ventilation control, oil management, temperature logging, management of warnings, and remote set-point or firmware update on equipment. This led to lowered use of raw materials used for cooking in addition to reduction in energy utilization and enhancing the kitchen operations.

About The Authors

Prateep Misra

Head of Technology and Engineering within the IoT Group at Tata Consultancy Services (TCS).

He has over 24 years' experience in the IT industry in areas such as software development, research, technology consulting, and software quality assurance. As a thought leader in TCS' Innovation Labs, Prateep has been responsible for setting up Centers of Excellence (CoEs) in areas such as stream processing, open storage, RFID and digital signal processing. His areas of expertise include embedded systems, RFID, IT infrastructure, real-time analytics and cloud computing. He holds a BTech in Instrumentation Engineering and an MTech in Electrical Engineering, both from the Indian Institute of Technology, Kharagpur.

Soumitra Naskar

Program Manager

He has over 17 years' experience cutting across multiple technology domains and verticals. His area of expertise include RFID, IT Infrastructure, cloud computing and embedded systems. Soumitra is currently working in the area of IoT platform development and infrastructure management. He holds a Bachelor's degree in Electrical Engineering from Jadavpur University, Kolkata.

Ritesh Ranjan

Platform Architect

He has over 12 years' experience in the IT industry in the area of software design and development, technology consulting and project management. Ritesh is currently responsible for managing security, performance and scalability of TCS Connected Universe Platform. His area of experise include RFID, NFC, Java/J2EE, Business Process Orchestration and Cloud and big data platforms. He holds a Master's degree in Computer Application from BIT, Mesra.

About Tata Consultancy Services Ltd (TCS)

Tata Consultancy Services is an IT services, consulting and business solutions organization that deliv ers real results to global business, ensuring a level of certainty no other firm can match. TCS offers a consulting-led, integrated portfolio of IT and IT-enabled, infrastructure, engineering and assurance services. This is delivered through its unique Global Network Delivery Model™, recognized as the benchmark of excellence in software development. A part of the Tata Group, India's largest industrial conglomerate, TCS has a global footprint and is listed on the National Stock Exchange and Bombay Stock Exchange in India.

For more information, visit us at www.tcs.com

Experience certainty. IT Services
Business Solutions
Consulting