IoT and its Application in Mining

For Five day PDP on

Personal Communication and Optical Monitoring System for Coal Mines

Koushik Mondal

koushik.ismd@gmail.com

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Outline of the Talk

- ✓ What is IOT?
- ✓ Technology adaptation (Short video)
- ✓ Challenges with existing systems
- ✓ Protocols Involved
- ✓ Layered Approach
- ✓ Digital Mining
- ✓ Applications of IOT in Mining
- ✓ Advantages
- ✓ Example

Internet of Things (IOT)

- ✓ Starting of formation of web services or open standards for industrial equipment and industrial communications paved the way for new technological advancements.

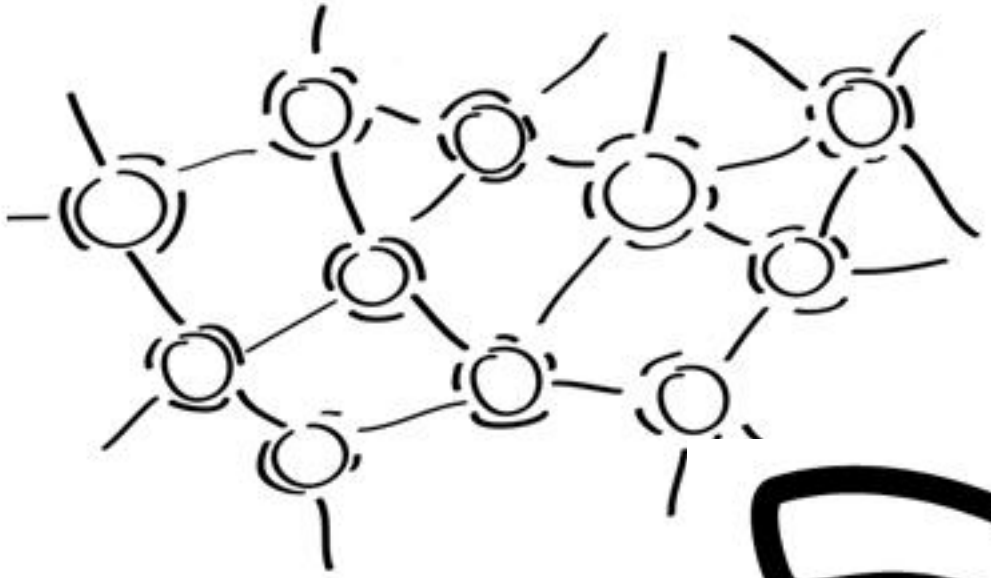
- ✓ As Operations Technology (OT) like SCADA, DCS, PLCs have been used for business critical operations at the mines, plants and supply chain operations, in the same line IOT can extend it beyond the OT domain.

- ✓ In the 2011 film **Limitless**, a struggling writer obtains a mysterious pill that enables him to access 100 percent of his brain abilities, helping him to reap monetary benefits by becoming a financial wizard. That magic pill is **IOT**.

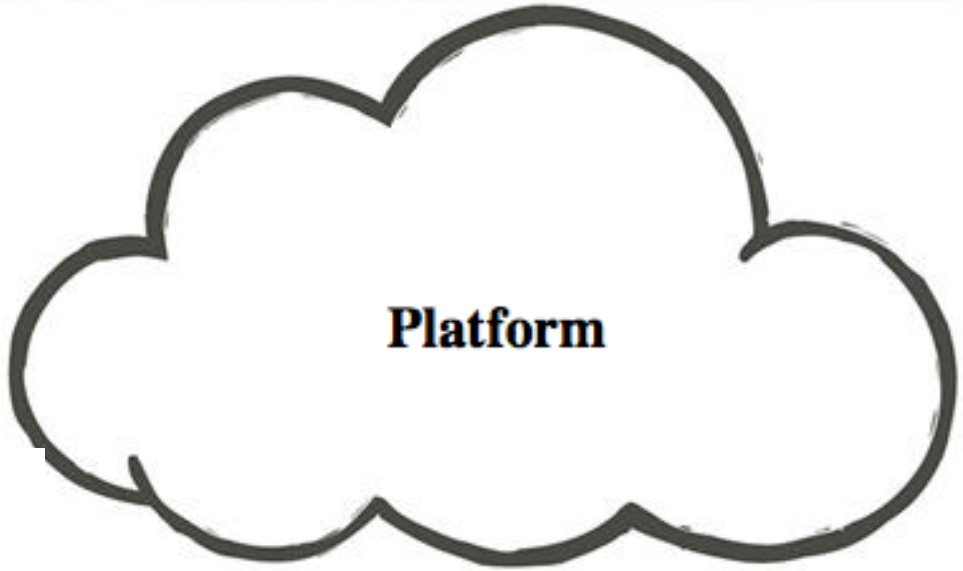
- ✓ Similar to the film, IOT also has the ability to empower mining equipment in order to function and operate with **optimal efficiency.**

- ✓ The IOT refers to the ever growing network of physical objects that feature an IP address for Internet connectivity, and the communication that occurs between these objects and Internet-enabled devices and systems.

What is IOT?

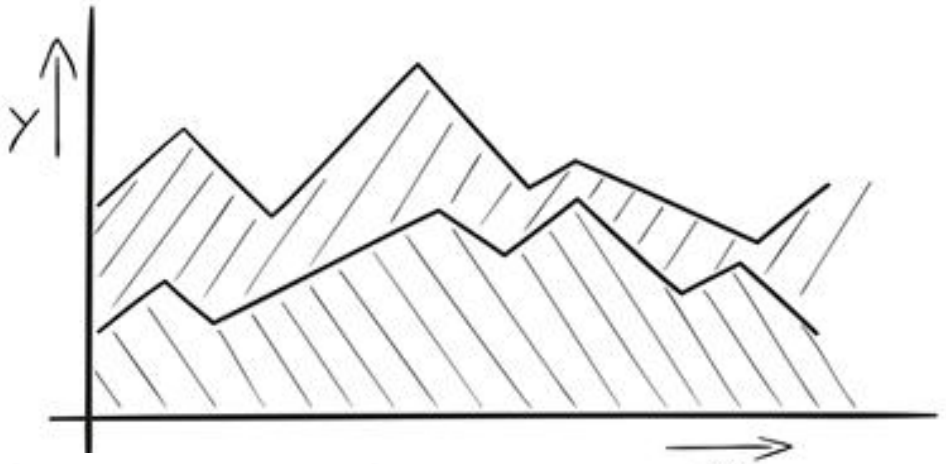


Sensors



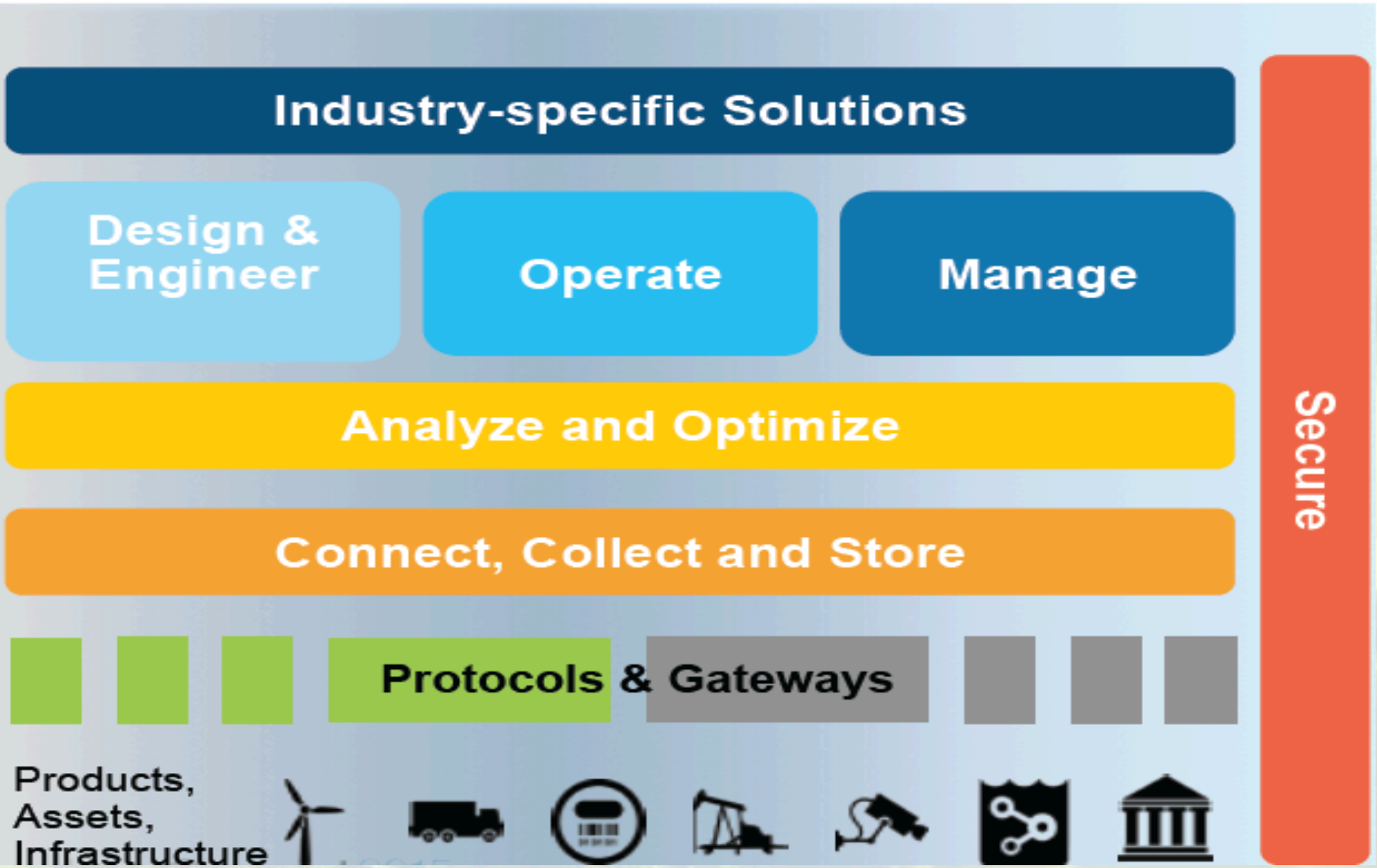
UI

Connectivity



Big Data Analytics

IOT Architecture



Design and Engineer
things and applications, addressing requirements management and complex system design processes

Operate
infrastructure safely and securely from rollout to production

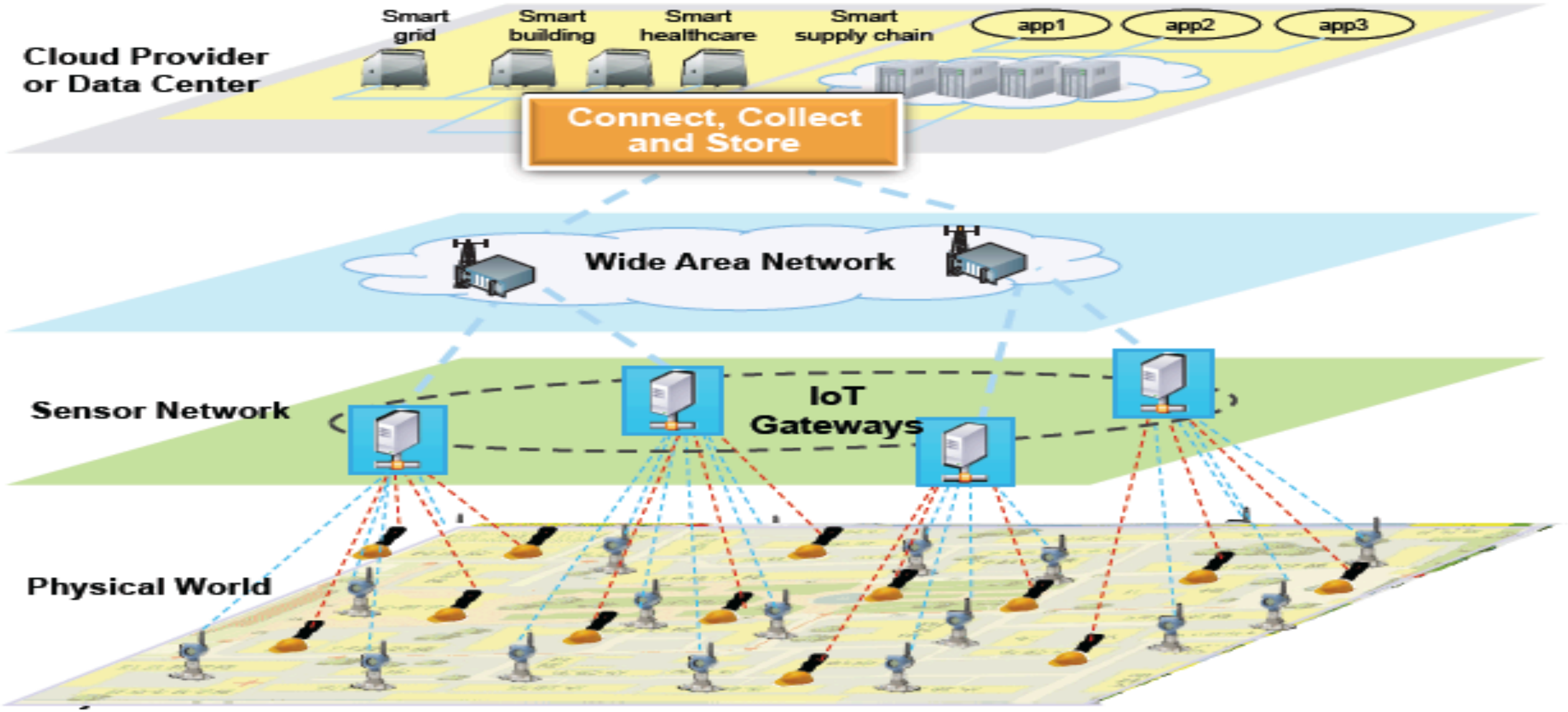
Manage
the lifecycle of things ensuring safe, reliable and predictive operations

Analyze & Optimize
information from across the lifecycle, leveraging insight for action

Connect, Collect and Store
information from a range of things with range of volume, variety and velocity

Secure
intelligence and action is critical from the thing up through industry solutions

IOT Architecture



Movie Clip

Coal mine collapsed 11 killed over 50 trapped

Police said the incident occurred during the shift change late on Thursday, and rescue operations could not be launched until the following morning due to fog and low light conditions. "The rescue operation was launched at 6 am on Friday. Eleven bodies have been taken out so far. We are focusing on saving the people still trapped inside the mine," said Godda superintendent of police Hira Lal Chauhan.

was nearly 300 metres deep. "It may take several months to dig them all out. About 26 Volvo trucks and six to seven bulldozers are still inside," he said.

blamed lack of safety measures at the mine for the tragedy. "The workers had raised objections in this regard. They even refused to work, but were forced by the management to do so," he said.

announced a compensation of `2 lakh each for the deceased's families, and `25,000 for the injured. Coal and renewable energy tweeted that an ex-gratia of `5 lakh would be paid for each person killed, in addition to compensation under the Workmen's Compensation Act.

Total compensation rollout is about 1 Crore INR + ++ some more to add

MAJOR MINING DISASTERS IN JHARKHAND

- December 27, 1975: In one of the India's worst mining disasters, 372 miners died in an explosion – followed by flooding – at the Chasnala coal mine of the Indian Iron and Steel Company (now SAIL) near Dhanbad.
- September 26, 1995: As many as 64 workers died at the Gajlitand colliery of the Bharat Coking Coal Limited (BCCL) in Katras area when rainfall caused flooding at the mine.
- February 2, 2001: Twenty-nine miners died at the BCCL's Bagdigi mines near Dhanbad. This disaster occurred when water from an adjoining mine flooded the one in which the victims were working.
- November 11, 2013: At least three mine workers and an officer were killed when the roof of an underground coal mine collapsed in the BCCL's Basanti Mata coal mine in Dhanbad. Over 160 workers were trapped.

Challenges with existing systems

- ✓ Lack of R&D
- ✓ Rising costs
- ✓ Health, Safety and Labour issues
- ✓ Low commodity prices
- ✓ Declining ore grades
- ✓ Inadequate infrastructure
- ✓ Technological “Prison”
- ✓ Regulatory pressure
- ✓ Low levels of exploration
- ✓ Weather

Protocols Involved

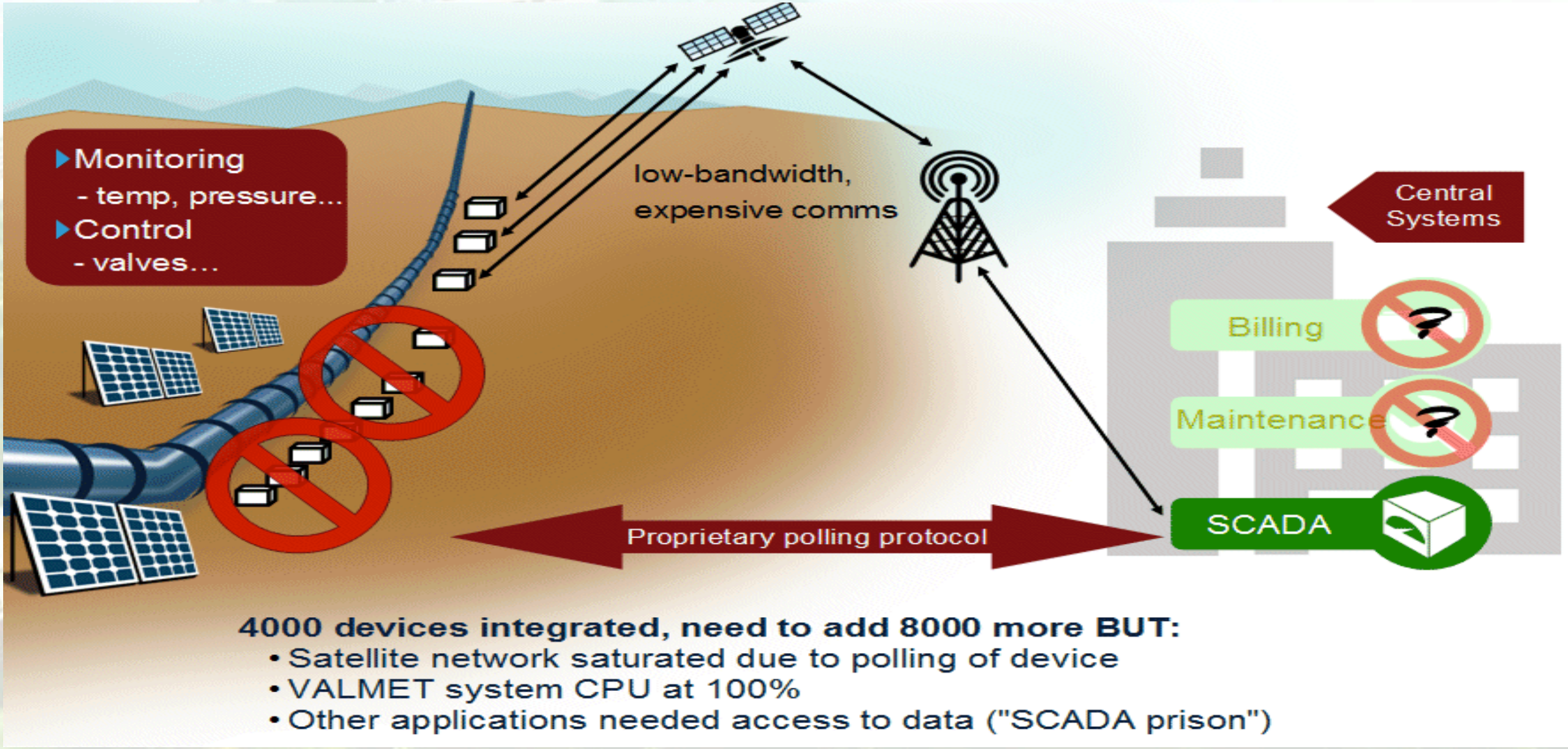
- ✓ Message Queuing Telemetry Transport (MQTT)
- ✓ Constrained Application Protocol (CoAP)
- ✓ Extensible Messaging and Presence Protocol (XMPP)
- ✓ Representational State Transfer (HTTP/RESTful)

Protocols Involved

Contd...

PROTOCOL	MQTT	CoAP	XMPP	HTTP/RESTful
Transport	TCP/IP	UDP	TCP/IP	TCP/IP
Messaging	Publish/ Subscribe; Request/ Response	Request/ Response	Publish/ Subscribe; Request Response	Request/ Response
Cellular Suitability (1000s nodes)	Excellent	Excellent	Excellent	Excellent
Low Power and Lossy Network (LLN)	Fair	Excellent	Fair	Fair
Primary Orientation	Message	Web service/ Document	Message	Web service/ Document
Energy/ power needs	Low	Low	High	High

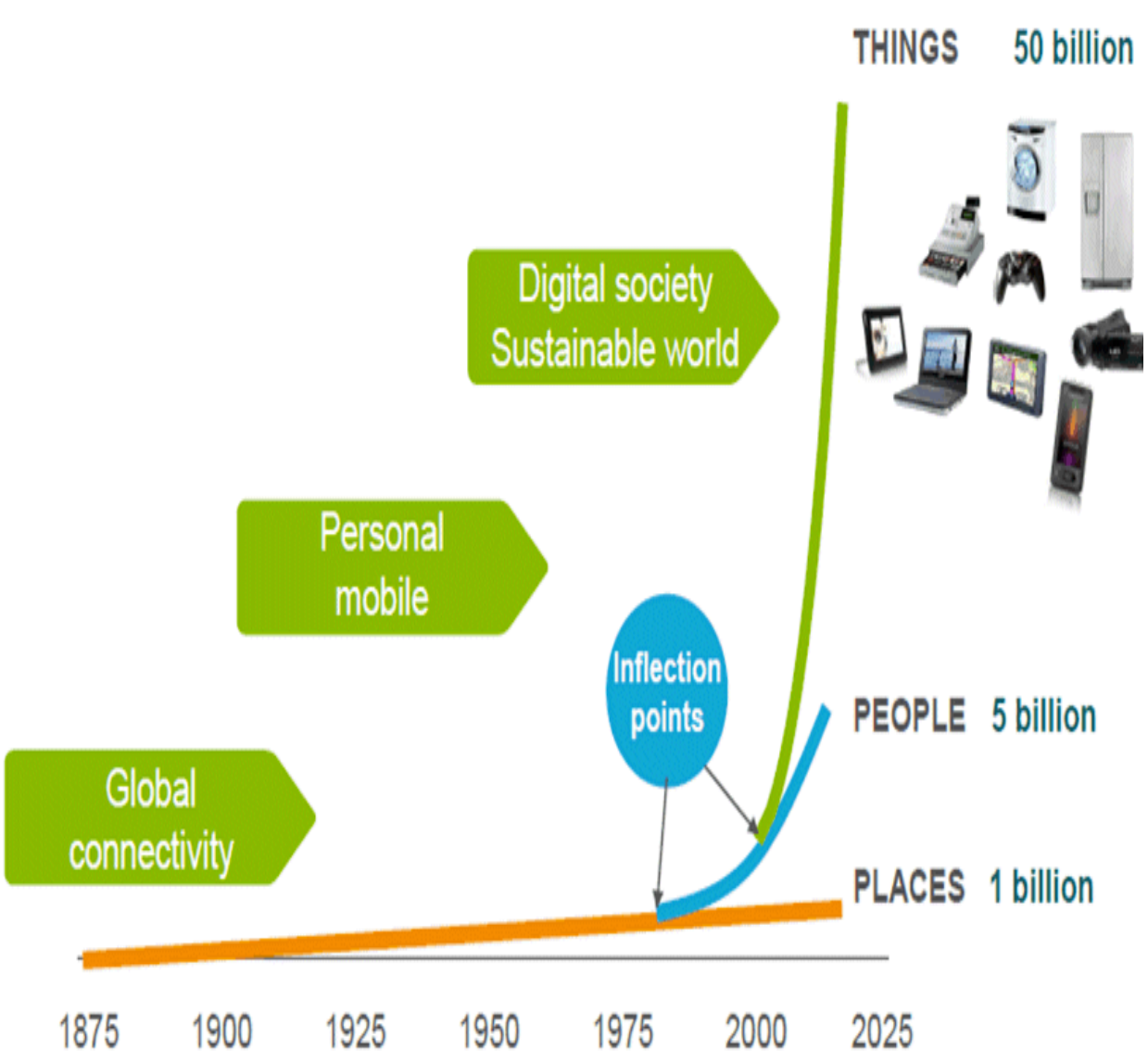
Operations Technology

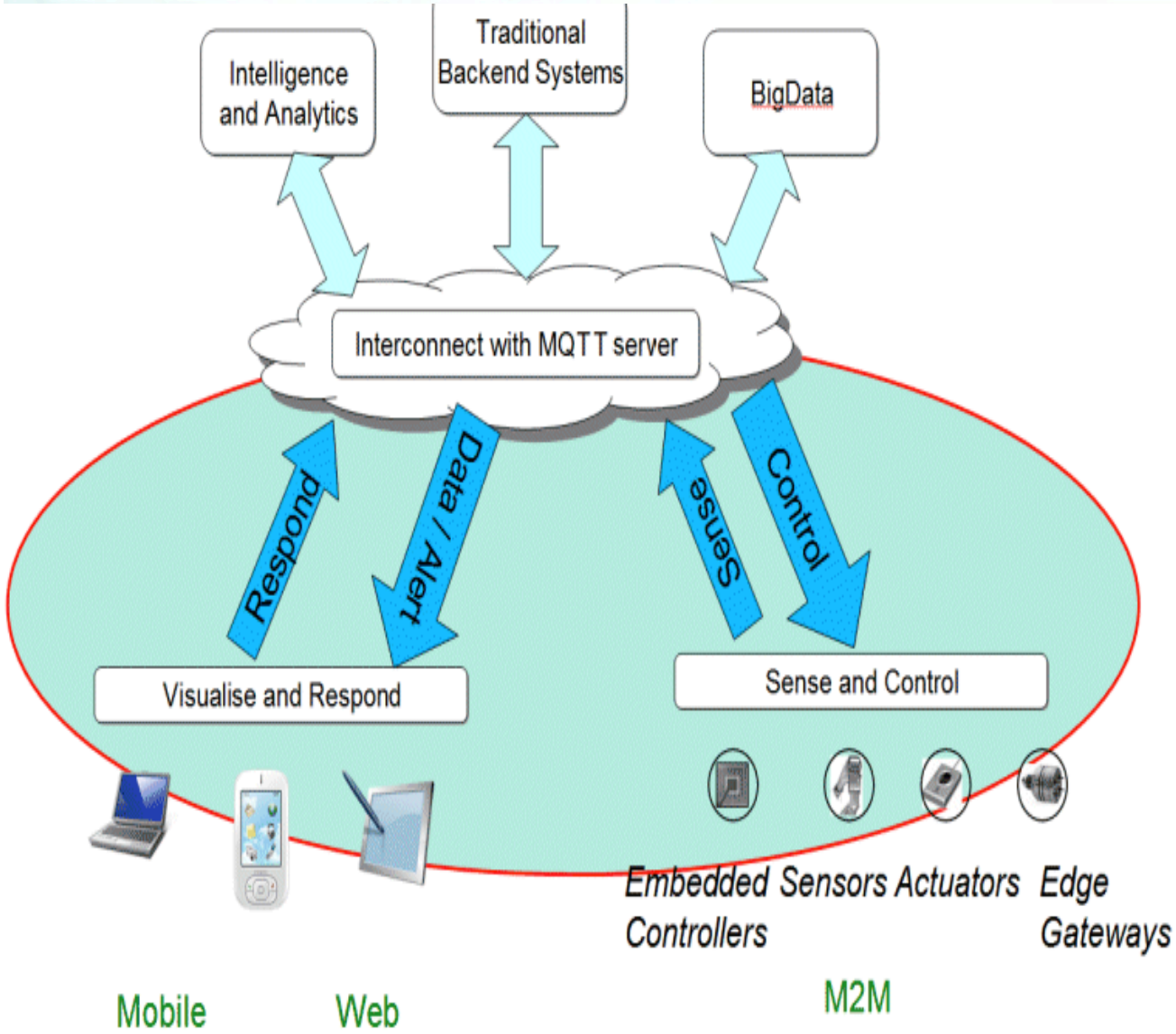


4000 devices integrated, need to add 8000 more BUT:

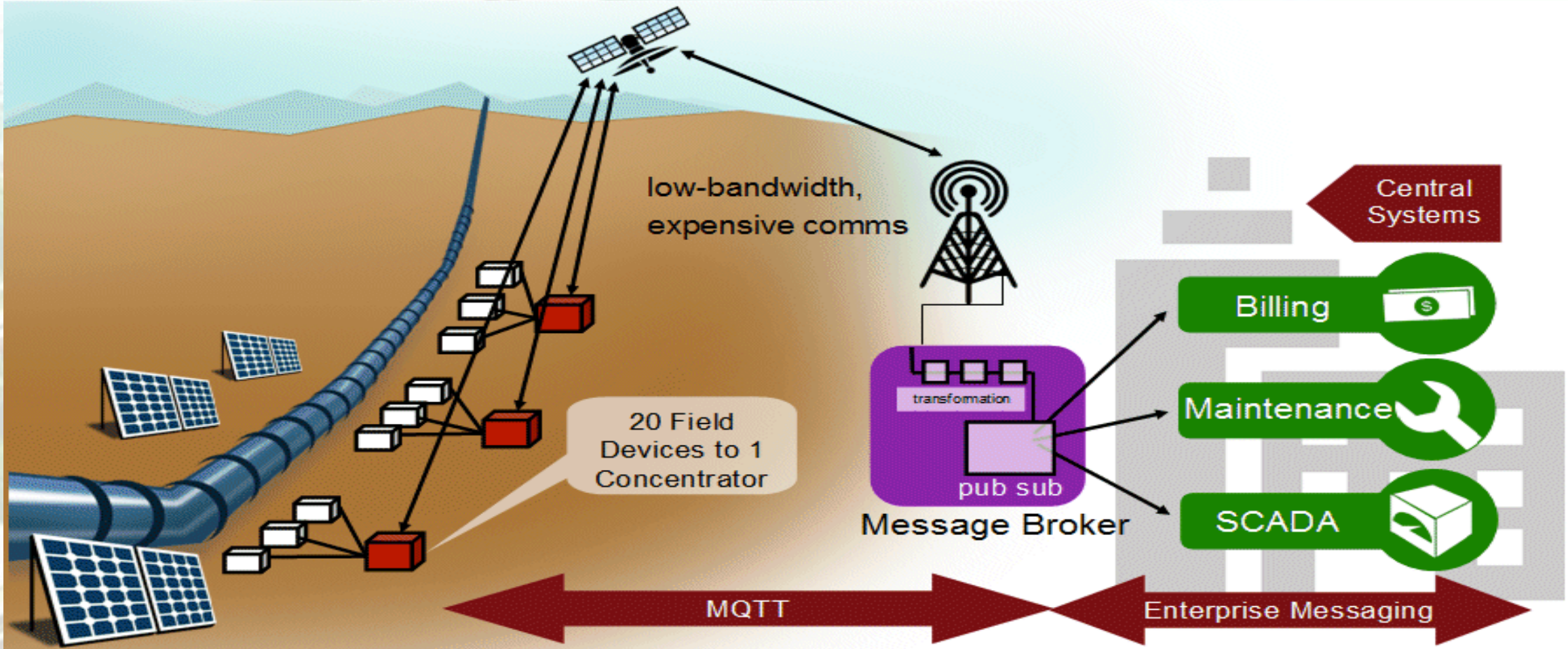
- Satellite network saturated due to polling of device
- VALMET system CPU at 100%
- Other applications needed access to data ("SCADA prison")

MQTT


THINGS 50 billion
Digital society
Sustainable world
Personal
mobile
Inflection
points
PEOPLE 5 billion
Global
connectivity
PLACES 1 billion
1875
1900
1925
1950
1975
2000
2025


Intelligence
and Analytics
Traditional
Backend Systems
BigData
Interconnect with MQTT server
Respond
Data / Alert
Sense
Control
Visualise and Respond
Sense and Control
Embedded Sensors Actuators Edge
Controllers
Gateways
Mobile
Web
M2M

OT with MQTT



Scalability for whole pipeline!
Network traffic much lower - events pushed to/from devices and report by exception
Network cost reduced
Lower CPU utilization
Broken out of the SCADA prison – data accessible to other applications

Layered Approach for initiating IOT

Design Step 0:

- Analyze sensory architecture. Assess the embedded sensors already in your products.
- Benchmark the product configuration with competitive offerings.
- Assess component/subassembly supplier parts range for embedded sensors.
- Humans-in-loop evaluation for your products and services.

Design Step 1:

- Create an IoT vision tailored to the organization. Evaluate ROI based on revenue models, efficiency savings and product differentiation.
- Design a blueprint for your organization's connected ecosystem, including suppliers, dealers, connected workforce and partners.
- Outline a customer experience design for achieving the IoT vision.

Design Step 2:

- Initiate engagement and employee communication. Engage and integrate employees, customers, process owners, operators and partners into the IoT program.
- Communicate with all stakeholders to solicit feedback on touch points and potential benefits to make it a win-win for all stakeholders involved.

Design Step 3:

- Focus on application development and infrastructure. Evaluate potential proliferation of personal connected devices within different stakeholder communities.
- Create a BYOD implementation plan (if one does not already exist), since this helps to prioritize employee-based applications.
- Decide on a common approach to development and deployment across multiple devices, including but not limited to data processing and visualization, device support protocols and integration with third-party data (Web services, APIs, etc.).

Design Step 4:

- Rapid deployment, monitoring and modification planning. Agile and flexible deployment with small, step-by-step implementations. The key is to get started with IoT and achieve incremental benefits

Design Step 5:

- Developing product features and embedded sensors You are now ready to exploit the potential with additional sensors and start building alliances and partnerships. These can help with further monetization and differentiation.

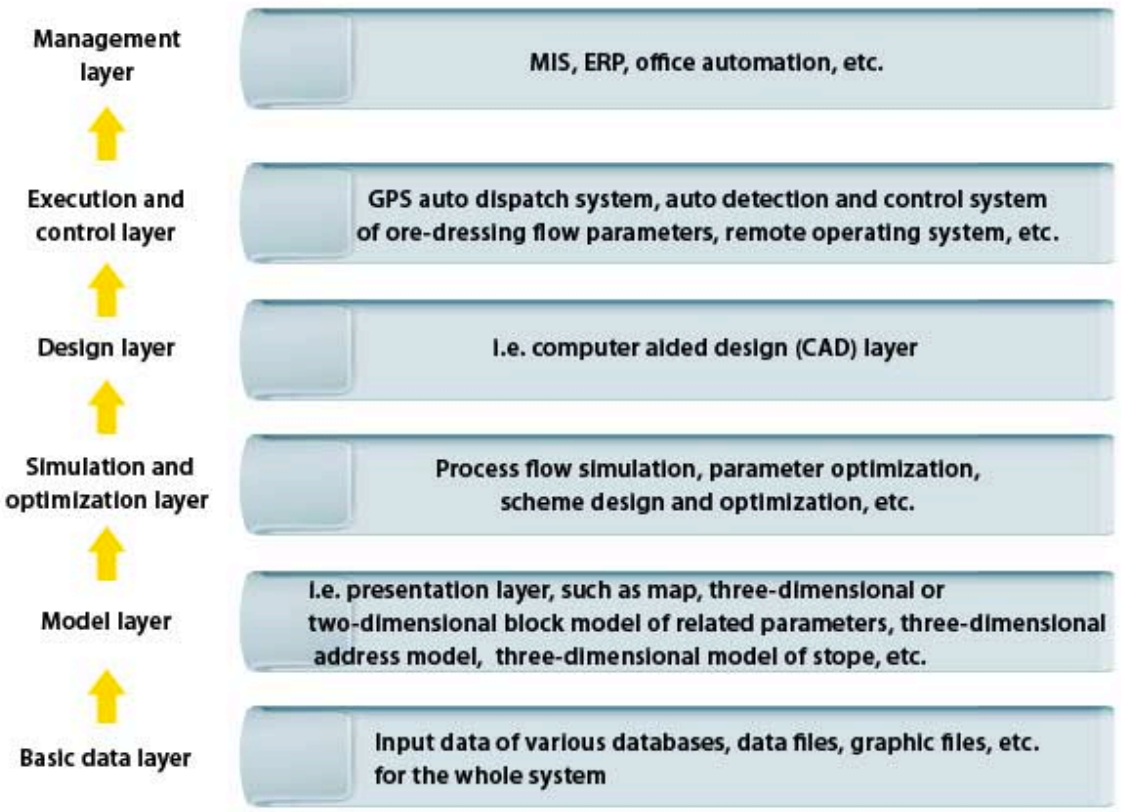
Digital Mining - Consideration for Mining

- Mine information highway system
- Wireless network coverage system for mining area
- 3D geological model system
- 3D deposit model system
- Data processing system for geologic measurement
- Ore grade evaluation system
- Slope stability detection system
- GPS vehicle intellectual dispatching system for strip mine
- GPS/GPRS dispatching system for railage
- Automatic mining planning system
- Integrated optimization system for opencast working
- Economy benefit analysis system for mining
- Equipment point inspection and post patrol information system
- Wireless industrial video supervision system
- Geological data rapid measurement analysis system
- Orientation system for underground personnel and equipment
- Automatic monitoring and early warning system for gangue safety
- Large-screen display system
- Safety early warning system for traveling in mining area

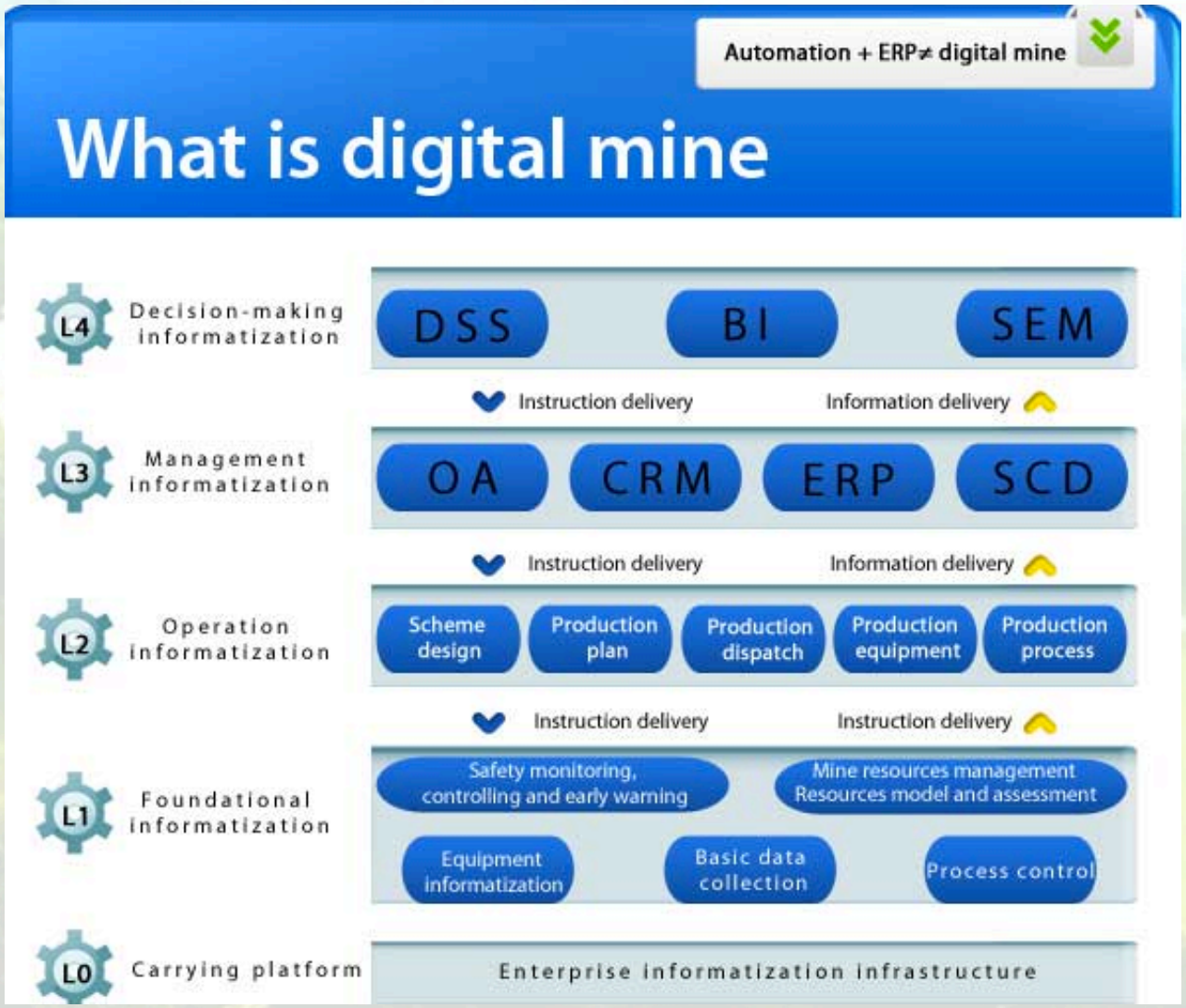
Digital Mining - Consideration for Dressing

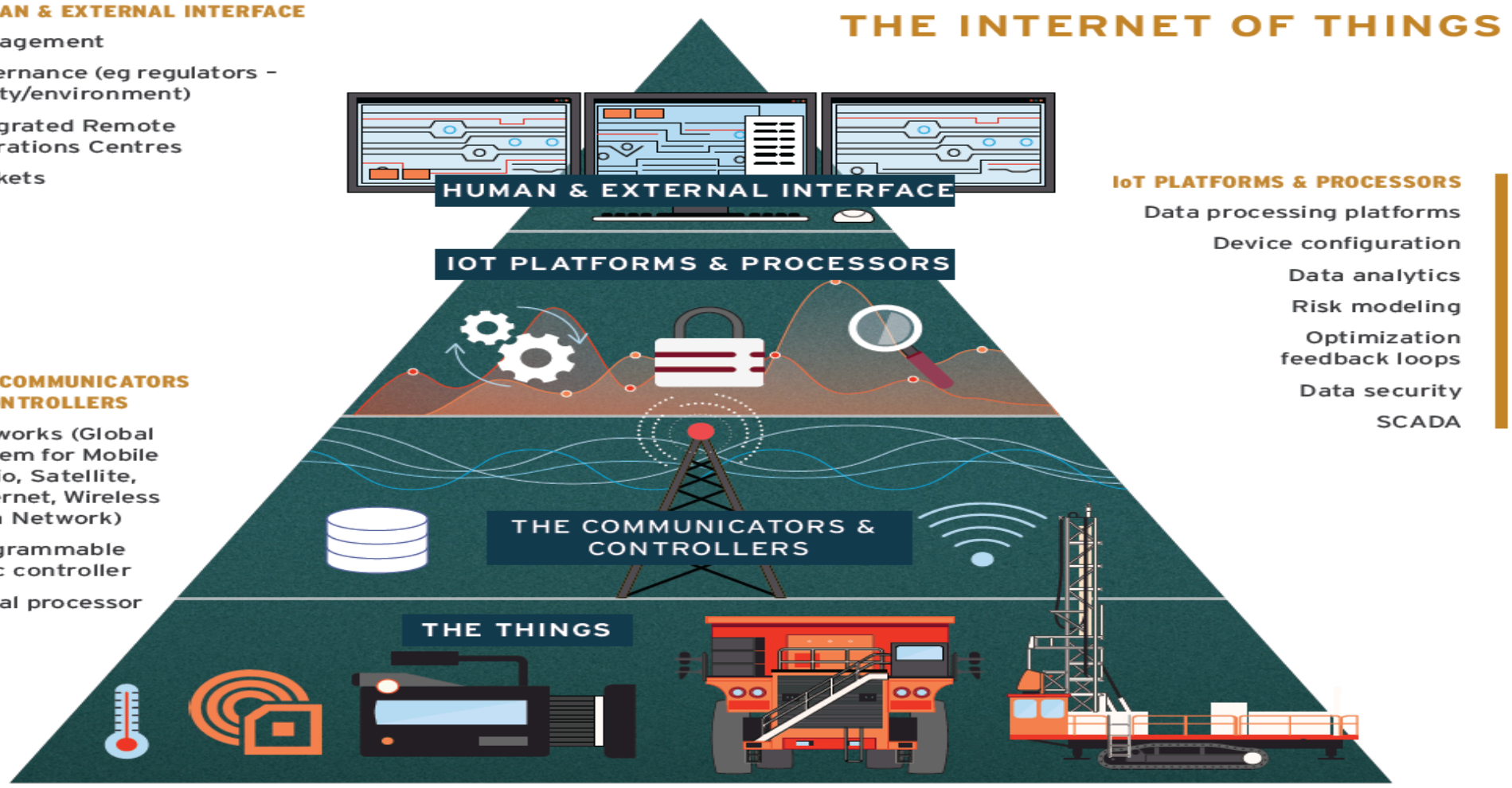
- Crushing automatic control system
- Grinding techniques information system
- Ventilation on demand
- Dehydration tank control system
- Magnetic separation column, cyclone and magnetic collector control system
- Filtration moisture control system
- Iron-increasing and silicon-decreasing control system
- Remote automatic control system for static pressure backwater
- Underflow automatic transportation control system
- Three water balancing automatic control system
- Whole process DCS system for dressing plant techniques

What is digital mine (system structure)



What is digital mine





HUMAN & EXTERNAL INTERFACE

- Management
- Governance (eg regulators – safety/environment)
- Integrated Remote Operations Centres
- Markets

IoT PLATFORMS & PROCESSORS

- Data processing platforms
- Device configuration
- Data analytics
- Risk modeling
- Optimization feedback loops
- Data security
- SCADA

THE COMMUNICATORS & CONTROLLERS

- Networks (Global System for Mobile Radio, Satellite, Ethernet, Wireless Area Network)
- Programmable logic controller
- Signal processor

THE THINGS

- Accelerometer
- Gyroscope
- Motors & pumps
- Pressure sensor
- Proximity sensor
- Thermometer
- Autonomous haulage truck
- Autonomous drilling rig
- Switch
- Gauge
- GPS
- RFID
- Video

Applications of IOT in mining

Mining Operation

- ✓ Full mine and plant automation driving a real-time machine and sensor level integration
- ✓ Remote monitoring & control of operations for real time fleet, drill, dumper tracking
- ✓ Monitoring fuel consumptions, engine and tire parameters etc. for mining assets
- ✓ Bringing data from multiple sources together driving real time mine dashboards, trends, operational alerts, and inventory tracking with advanced analytical capabilities.
- ✓ Capturing sensor data from moving equipment, driving real time movement controls.
- ✓ Integrating data from mining expert systems to drive concepts like Ore grade sensing
- ✓ Connected business management driving integrated business process workflows
- ✓ Mine worker productivity- activity tracking, productive and nonproductive work time etc.
- ✓ Digital monitoring and modelling of mine site, mining progress and ongoing changes etc.
- ✓ Fleet Driver/driving behavior and driving condition analytics at mine site

Asset Maintenance

- ✓ Predictive maintenance and diagnostics
- ✓ Real-time asset condition monitoring
- ✓ Remote asset maintenance
- ✓ Better collaboration between OEM and equipment operators driving connected process on network for assets
- ✓ Location based maintenance and support services etc.

Commodity Supply Chain

- ✓ Real time tracking and traceability of mining fleets and commodity inventories from pit to port
- ✓ Fleet planning/ diagnostics using communication data & RFID /sensor level connectivity
- ✓ Real time logistics information and location intelligence
- ✓ Integrated and automated port equipment management and operations

EH&S and Sustainability

- ✓ Tracking and tracing of mine workers location using RFID, mine worker location intelligence
- ✓ Mine working environment condition monitoring
- ✓ Access control and monitoring at mine site, geo fencing
- ✓ Monitoring Gas concentration/ventilation in underground mines & improving disaster predictions
- ✓ Collision detection of mining equipment and people safety
- ✓ Integrated wearable devices to monitor hazardous exposure and fatigue
- ✓ Fully real time and connected emission and Sustainability reporting
- ✓ Energy tracking and optimization at mining and processing plants

One HME (Hendrickson Mobile Equipment) Truck having ~200 sensors

32 Sensors

120 Sensors

40 Sensors

If ~500 such trucks are there and 85% trucks are utilized in mining thus approximate data generation is about 2.5 - 3.0 TB/day

A significant value to leverage.

Is it a Big Data Application?

Advantages

✓ **Predicting downtime**

Because IoT makes sense of large amounts of data captured from machines, it uncovers valuable insight into the health and performance of equipment and infrastructure.

For example, General Electric is developing a sensor network based on the principles of IoT to monitor turbines constantly in order to reduce downtime.

Mining companies can measure in real-time things like

- fluid temperatures, levels, pressures, contamination;
- bearing rotations, temperature, and vibrations;
- frame rack, bias, and pitch (affected by load and road conditions);
- engine speed and gear position; brake pressure and temperature;
- drive train performance; and vibrations at various locations in the truck (especially bearings).

These predictive analytics help identify impending problems early in order to avoid unexpected downtimes or failures.

✓ Increasing Efficiency

The Internet of Things will allow companies to improve efficiency and service by enabling physical objects like haul trucks-embedded with electronics, software and sensors--to exchange data with manufacturers and other machines and connected devices. Think about it: giant trucks on programmed and responsive routes hauling ore autonomously, while drones monitor and measure surface operations and equipment is located, scheduled and monitored with adaptive feedback loops to maximize production.

By improving truck availability or reducing downtime, and improving the diagnostics and troubleshooting capabilities of the mine operations and maintenance teams, companies can greatly enhance the efficiency of mine operations.

- ✓ **Revolutionize Safety**

Along with incorporating location/proximity sensors and warning technology in mining equipment, companies will use the Internet of Things to integrate people tracking, communications, video surveillance and analytics, and real-time personal health management.

Simply put, the Internet of Things will enable companies to continuously improve its safety by analyzing hazards, incidents, near misses and safety observations. By connecting machines, data and people together, companies can not only perform better, faster and more reliable but safety risks are a thing of the past.

- ✓ **Decision Making**

The Internet of Things is expected to be a catalyst to intelligent decision making in the mining sector and will overall improve how traditional processes and activities are done. For example, GPS tracking of material movements, as well as camera views of production, further improve the planners' decisions, providing all production information, including materials, logistics, schedules, and energy, across the plant supply chain. The IOT has the ability to streamline the flow of information, enable real-time decisions and open new opportunities in mining by simply connecting people, machines, items, and services.

✓ Seamless Automation

The mining industry is already leveraging the Internet of Things in wireless mining automation and connected mines projects. Since 2008, Rio Tinto has been using autonomous, self-driving mining trucks in Western Australia and Fortescue Metals Group began their journey with Caterpillar in 2012 when the miner implemented Cat's MineStar technology in the first phase of their Solomon iron ore mine in Australia.

By integrating the Internet of Things with all of its automated activities, mining companies can create real-time multi-dimensional models from a variety of data sources including the sensors on the equipment as well as geological and other data. Therefore this system can then be used to optimize the mine's layout, operation, vehicle paths, and so forth, coordinating all the moving pieces for the most efficient operation.

✓ On-demand Ventilation Systems

One of the reasons that mines can be dangerous for humans is that they're often filled with contaminants that are hazardous to breathe in. Thus, it's essential that mines provide fresh air to workers so they remain healthy and unharmed.

Today, remotely controlled or on-demand ventilation systems have been created for mines, which make much healthier environments for workers. On-demand ventilation systems often have automatic technology that can read the amount of contamination in the air and adjust ventilation accordingly. Other Internet-connected ventilation systems allow controllers and monitors to adjust the ventilation manually from a remote control center.

Temperature and Pressure Tracking: Xcambo

```
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ python
python
python-argcomplete-check-easy-install-script
python-config
....
python2.7
Pythonw
...
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ pip install psutil paho-mqtt
Requirement already satisfied (use --upgrade to upgrade): psutil in ./anaconda/lib/python2.7/site-packages
Collecting paho-mqtt
  Downloading paho-mqtt-1.2.tar.gz (49kB)
    100% |████████████████████████████████| 51kB 123kB/s
Building wheels for collected packages: paho-mqtt
  Running setup.py bdist_wheel for paho-mqtt ... done
  Stored in directory: /Users/koushikmondal/Library/Caches/pip/wheels/fa/db/fb/
b495e37057e2f40534726b3c00ab26a58fc80fb8d17223df07
Successfully built paho-mqtt
Installing collected packages: paho-mqtt
Successfully installed paho-mqtt-1.2
```

Temperature and Pressure Tracking: Xcambo

Contd…

```
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ wget https://launchpad.net/python-weather-api/trunk/0.3.8/+download/
                                                pywapi-0.3.8.tar.gz
--2017-02-07 22:14:02--  https://launchpad.net/python-weather-api/trunk/0.3.8/+download/pywapi-0.3.8.tar.gz
Resolving launchpad.net... 91.189.89.222, 91.189.89.223
Connecting to launchpad.net|91.189.89.222|:443... connected.
HTTP request sent, awaiting response... 302 Moved Temporarily
Location: https://launchpadlibrarian.net/166317636/pywapi-0.3.8.tar.gz [following]
--2017-02-07 22:14:04--  https://launchpadlibrarian.net/166317636/pywapi-0.3.8.tar.gz
Resolving launchpadlibrarian.net... 91.189.89.228, 91.189.89.229
Connecting to launchpadlibrarian.net|91.189.89.228|:443... failed: Operation timed out.
Connecting to launchpadlibrarian.net|91.189.89.229|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 25166 (25K) [application/x-tar]
Saving to: 'pywapi-0.3.8.tar.gz'

pywapi-0.3.8.tar.gz 100%[===================>]  24.58K   123KB/s    in 0.2s

2017-02-07 22:15:21 (123 KB/s) - 'pywapi-0.3.8.tar.gz' saved [25166/25166]
```

Temperature and Pressure Tracking: Xcambo

Contd…

```
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ tar zvxf pywapi-0.3.8.tar.gz
x pywapi-0.3.8/examples/pywapi-countries-example.py
x pywapi-0.3.8/setup.py
x pywapi-0.3.8/MANIFEST
x pywapi-0.3.8/examples/
x pywapi-0.3.8/examples/pywapi-noaa-example.py
x pywapi-0.3.8/examples/pywapi-example.py
x pywapi-0.3.8/pywapi.pyc
x pywapi-0.3.8/LICENSE
x pywapi-0.3.8/examples/pywapi-weather-com-example.py
x pywapi-0.3.8/pywapi.py
x pywapi-0.3.8/examples/pywapi-cities-example.py
x pywapi-0.3.8/CHANGELOG
x pywapi-0.3.8/README
x pywapi-0.3.8/
x pywapi-0.3.8/examples/pywapi-yahoo-example.py
x pywapi-0.3.8/examples/get-weather.py
```

```
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ cd pywapi-0.3.8
Koushik-Mondals-MacBook-Pro:pywapi-0.3.8 koushikmondal$ python setup.py build
running build
running build_py
creating build
creating build/lib
copying pywapi.py -> build/lib
Koushik-Mondals-MacBook-Pro:pywapi-0.3.8 koushikmondal$ python setup.py install
running install
running build
running build_py
running install_lib
copying build/lib/pywapi.py -> /Users/koushikmondal/anaconda/lib/python2.7/site-packages
byte-compiling /Users/koushikmondal/anaconda/lib/python2.7/site-packages/pywapi.py to pywapi.pyc
running install_egg_info
Writing /Users/koushikmondal/anaconda/lib/python2.7/site-packages/pywapi-0.3.8-py2.7.egg-info
Koushik-Mondals-MacBook-Pro:pywapi-0.3.8 koushikmondal$ cd ..
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ rm -rf pywapi-0.3.8*
```

Temperature and Pressure Tracking: Xcambo

Contd…

```
Koushik-Mondals-MacBook-Pro:~ koushikmondal$ cd Desktop/IoTinMining/CodeLab/Xcambo/
Koushik-Mondals-MacBook-Pro:Xcambo koushikmondal$ sh setup.sh

Welcome to Xcambo Playground
setup.sh: line 8: cd: CodeLabs/Xcambo/: No such file or directory
Collecting pip
  Downloading pip-9.0.1-py2.py3-none-any.whl (1.3MB)
    100% |████████████████████████████████| 1.3MB 290kB/s
Installing collected packages: pip
  Found existing installation: pip 8.1.2
    …
Collecting psutil (from -r requirements.pip (line 1))
  Downloading psutil-5.1.2.tar.gz (341kB)
    100% |████████████████████████████████| 344kB 627kB/s
Collecting paho-mqtt (from -r requirements.pip (line 2))
Building wheels for collected packages: psutil
  Running setup.py bdist_wheel for psutil ... done
  Stored in directory: /Users/koushikmondal/Library/Caches/pip/wheels/fc/1a/6e/
f8c70ab9ec7b482151fbd972750b6508d2f8d8f4e673c3d537
```

Temperature and Pressure Tracking: Xcambo

Successfully built psutil
Installing collected packages: psutil, paho-mqtt
Successfully installed paho-mqtt-1.2 psutil-5.1.2

Koushik-Mondals-MacBook-Pro:Xcambo koushikmondal$ python main.py

Hello Xcambo
Data Sensor: 50989843
API Weather: Guadalajara, JO, Mexico, Temperature 18 C, Atmospheric Pressure 844 mbar

Hello Xcambo
Data Sensor: 50989948
API Weather: Guadalajara, JO, Mexico, Temperature 18 C, Atmospheric Pressure 844 mbar

Hello Xcambo
Data Sensor: 50989983
API Weather: Guadalajara, JO, Mexico, Temperature 18 C, Atmospheric Pressure 844 mbar

Temperature and Pressure Tracking: Xcambo

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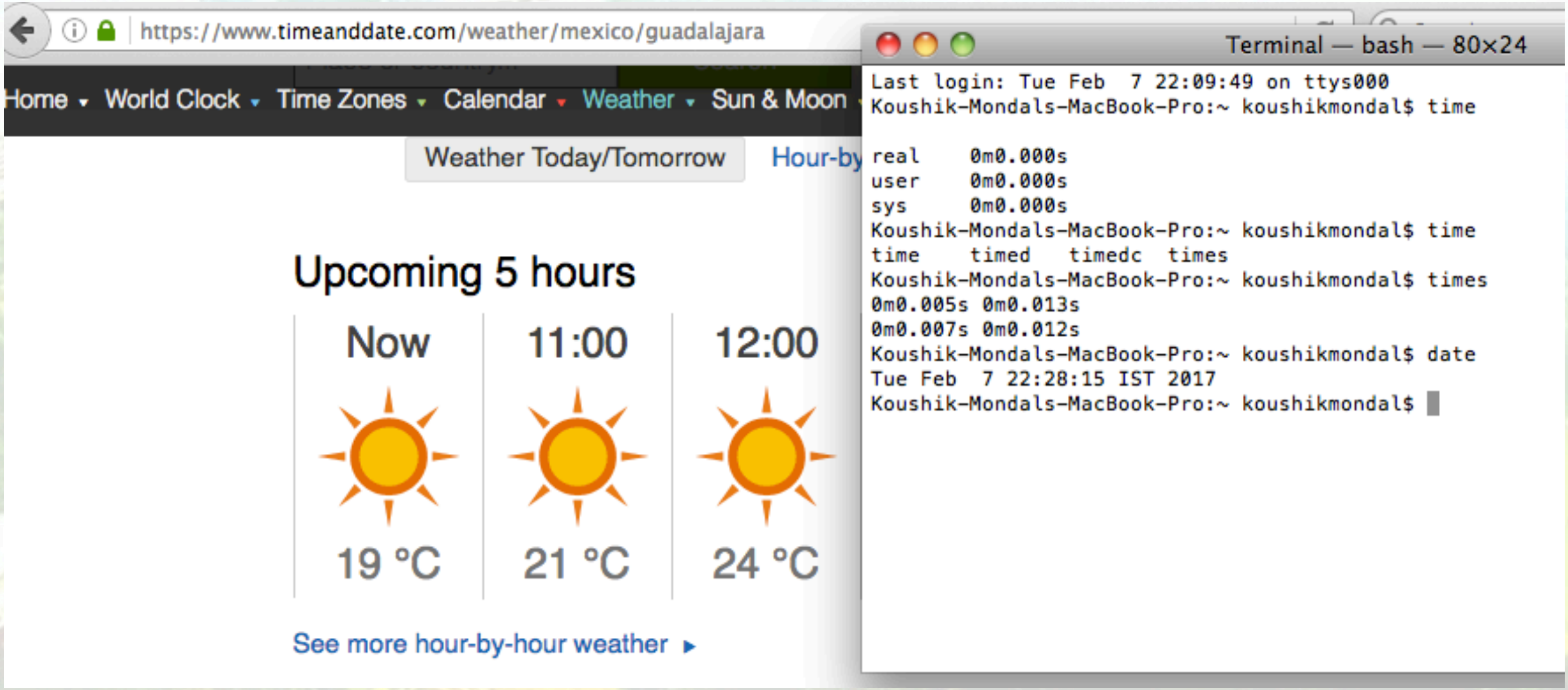

Movie Clip

Perfection is not attainable. But if we chase perfection, we can catch excellence.

Vince Lombardi

gemkousk@gmail.com