A Proposed API for the Information Plane of the WSN Integrated Technical Reference Model (I-TRM)

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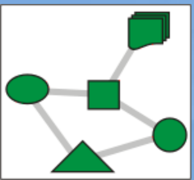
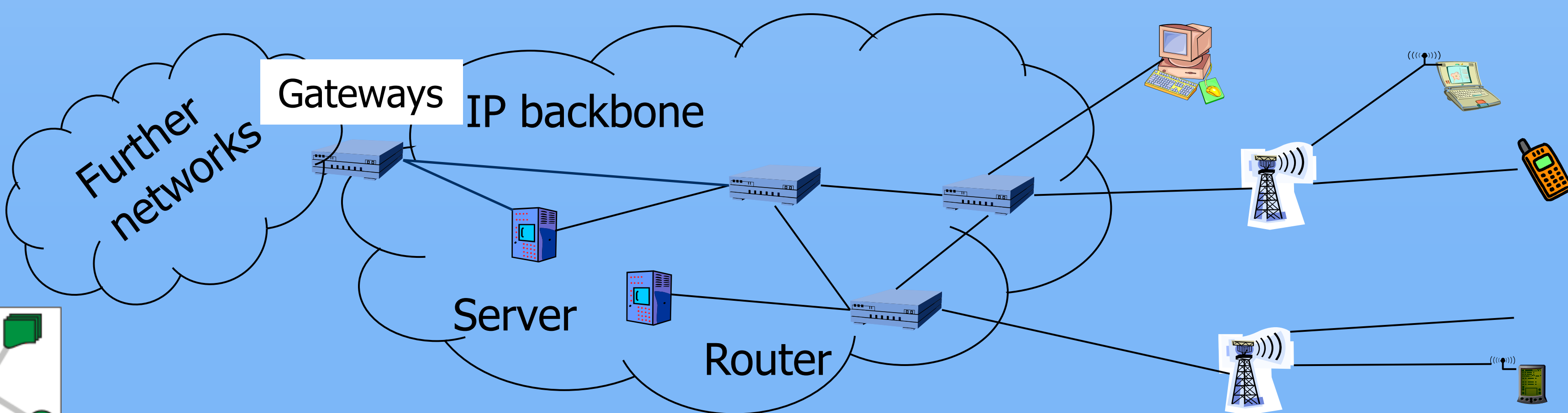


INTRODUCTION

Infrastructure-based wireless networks

- Typical wireless network: Based on infrastructure
  - E.g., GSM, UMTS, …
  - Base stations connected to a wired backbone network
  - Mobile entities communicate wirelessly to these base stations
  - Traffic between different mobile entities is relayed by base stations and wired backbone
  - Mobility is supported by switching from one base station to another
  - Backbone infrastructure required for administrative tasks

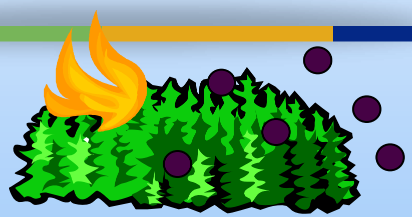


Infrastructure-based wireless networks – Limits?

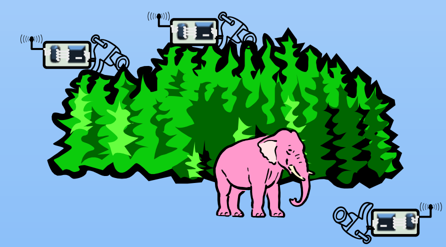
- What if …
  - No infrastructure is available? – E.g., in disaster areas
  - It is too expensive/inconvenient to set up? – E.g., in remote, large construction sites
  - There is no time to set it up? – E.g., in military operations

Wireless Sensor Network (WSN) Application Examples

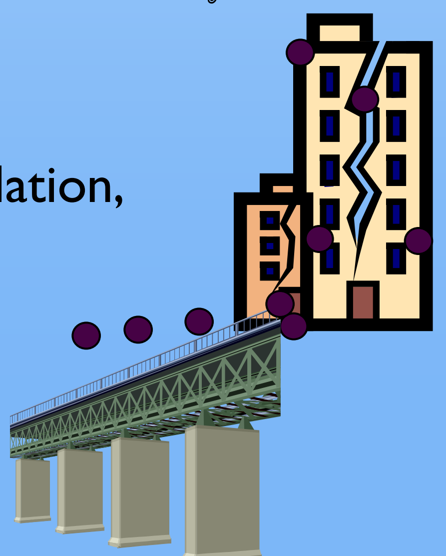
- Disaster relief operations
  - Drop sensor nodes from an aircraft over a wildfire
  - Each node measures temperature
  - Derive a "temperature map"

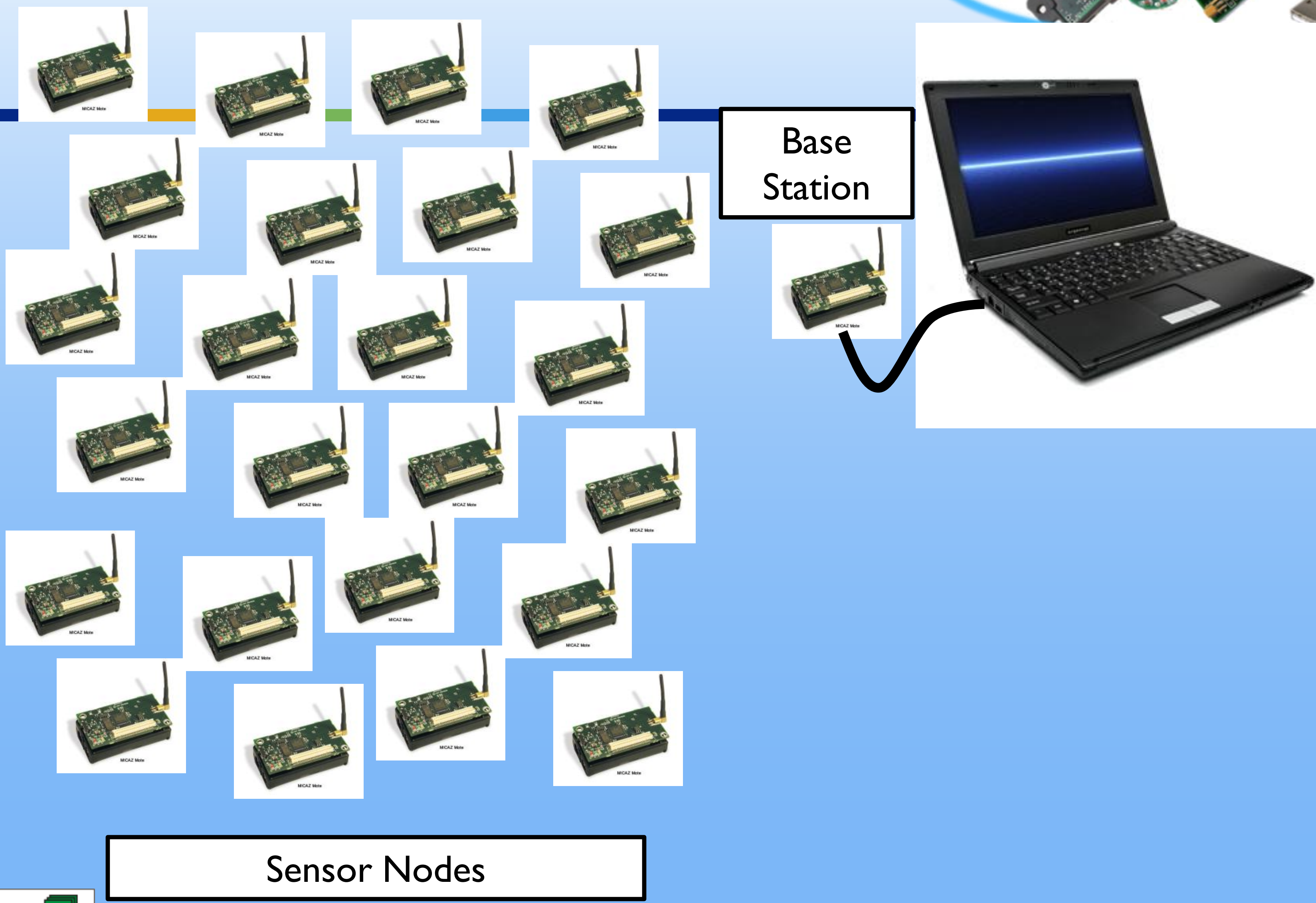


- Biodiversity mapping
  - Use sensor nodes to observe wildlife

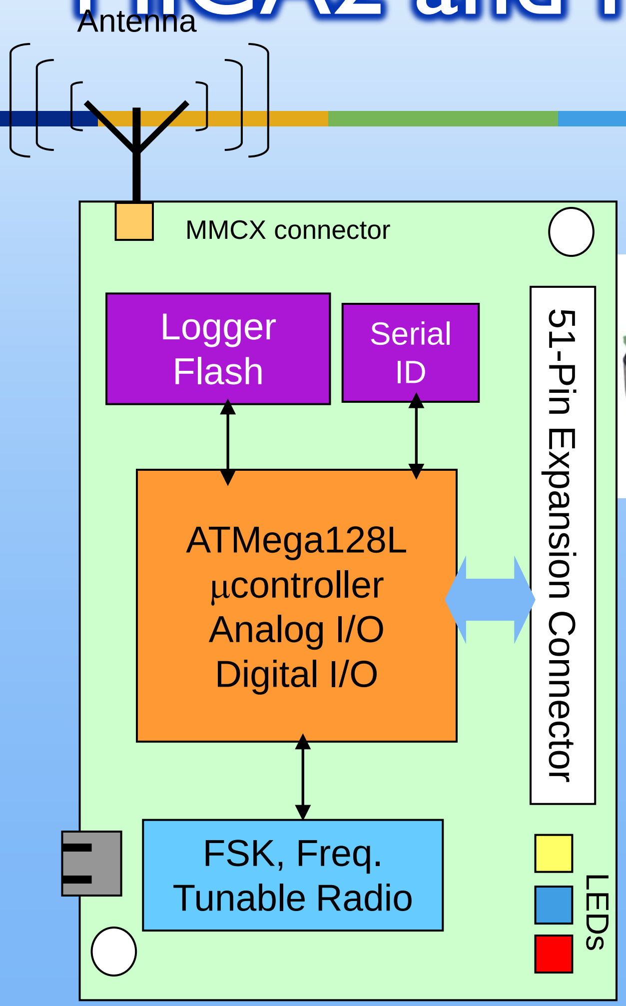


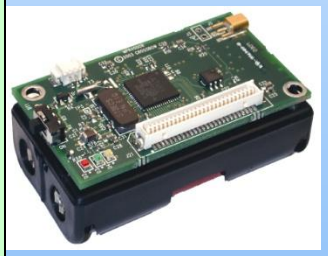
- Intelligent buildings (or bridges)
  - Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control
  - Needs measurements about room occupancy, temperature, air flow, …
  - Monitor mechanical stress after earthquakes

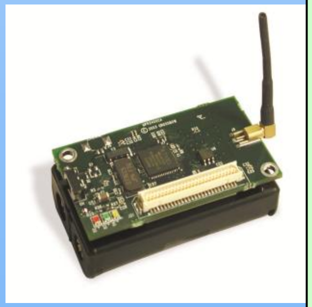


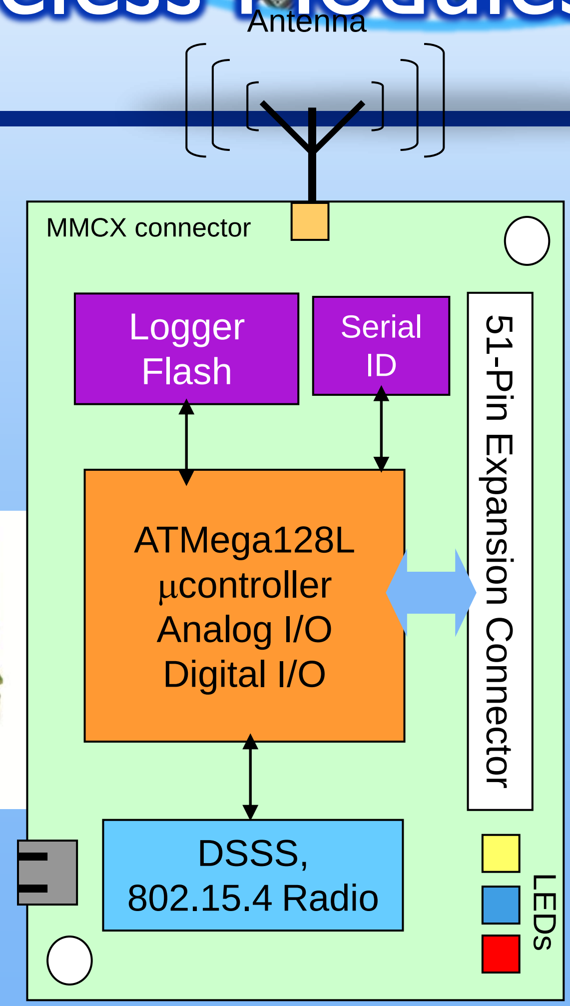

Base Station
Sensor Nodes

MICA2 and MICAz Wireless Modules









MICA2
(MPR400, MPR410, MPR420)

FCC/ARIB certified

MICAz
(MPR2400)

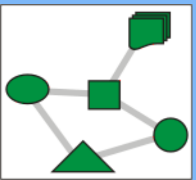
MICAz and MICA2 Core Hardware Components

Platform	MICAz	MICA2	Information
Microprocessor	ATmega128L	ATmega128L	http://www.atmel.com
Radio	CC2420 (2.4 GHz)	CC1000 (433 MHz, 868/916 MHz)	http://www.chipcon.com/
External Serial Flash	AT45DB041 512 Kbyte	AT45DB041 512 Kbyte	http://www.atmel.com The serial flash can be used for over-the-air-programming (OTAP) and/or data logging
Unique ID (integrated circuit)	DS2401P 64-bit	DS2401P 64-bit	http://www.maxim-ic.com/ This chip contains a unique 64 bit identifier.
51-Pin expansion connector	Yes, except for OEM modules	Yes, except for OEM modules	This connector brings out most of the ATmega128L signal

PROBLEM STATEMENT

What is this Research all about?

- To develop an architecture for an
  - Autonomous Sensor Network
  - which is self-aware and adaptable to changes
    - within itself
    - its tasking and
    - its environment

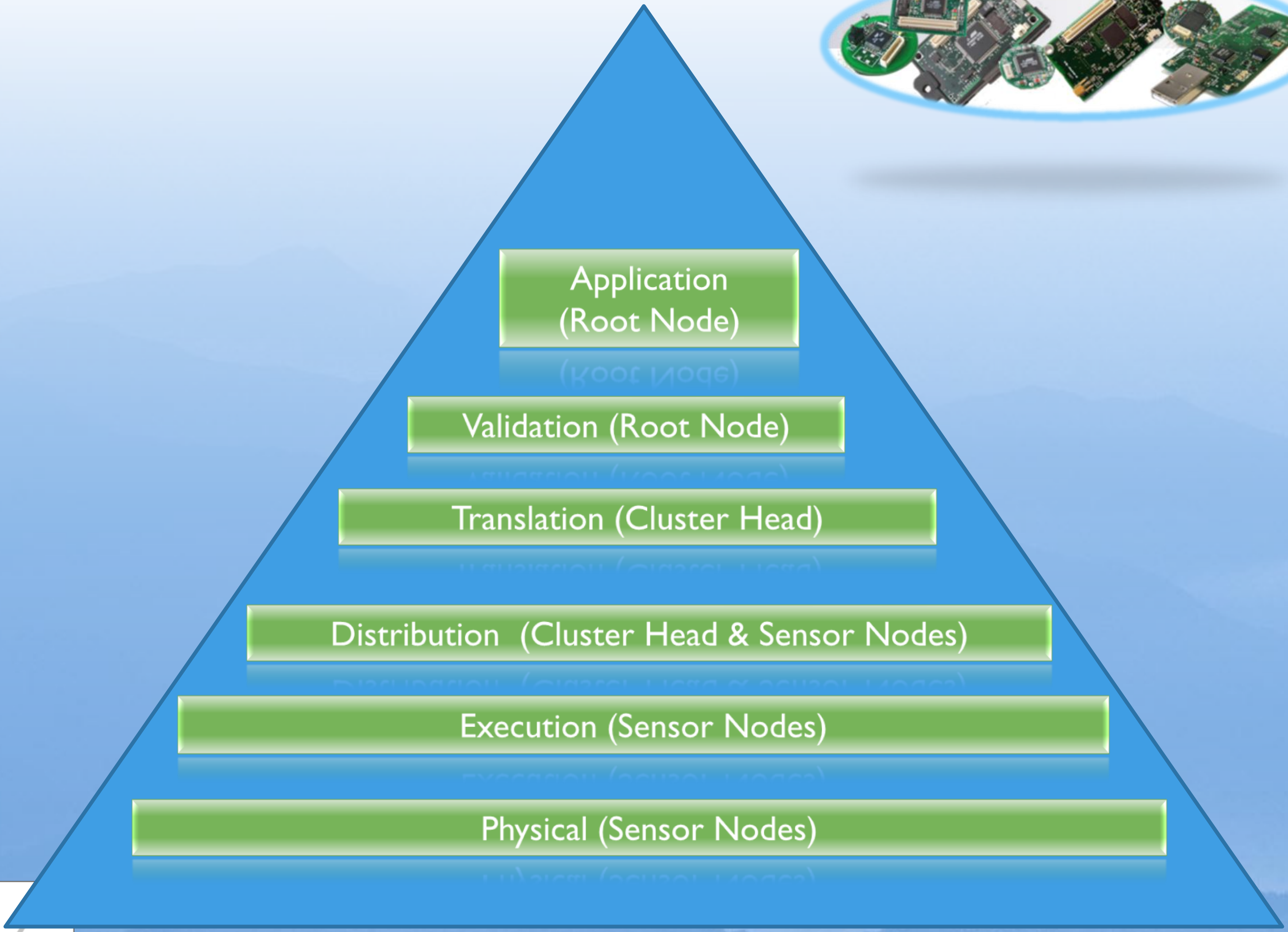


Three Integral Aspects of Autonomous Systems

- Information Processing
- Control Distribution and Implementation
- Working (Behavior) of System, Sub-Systems and Components

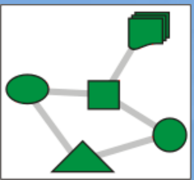
Control Technical Reference Model

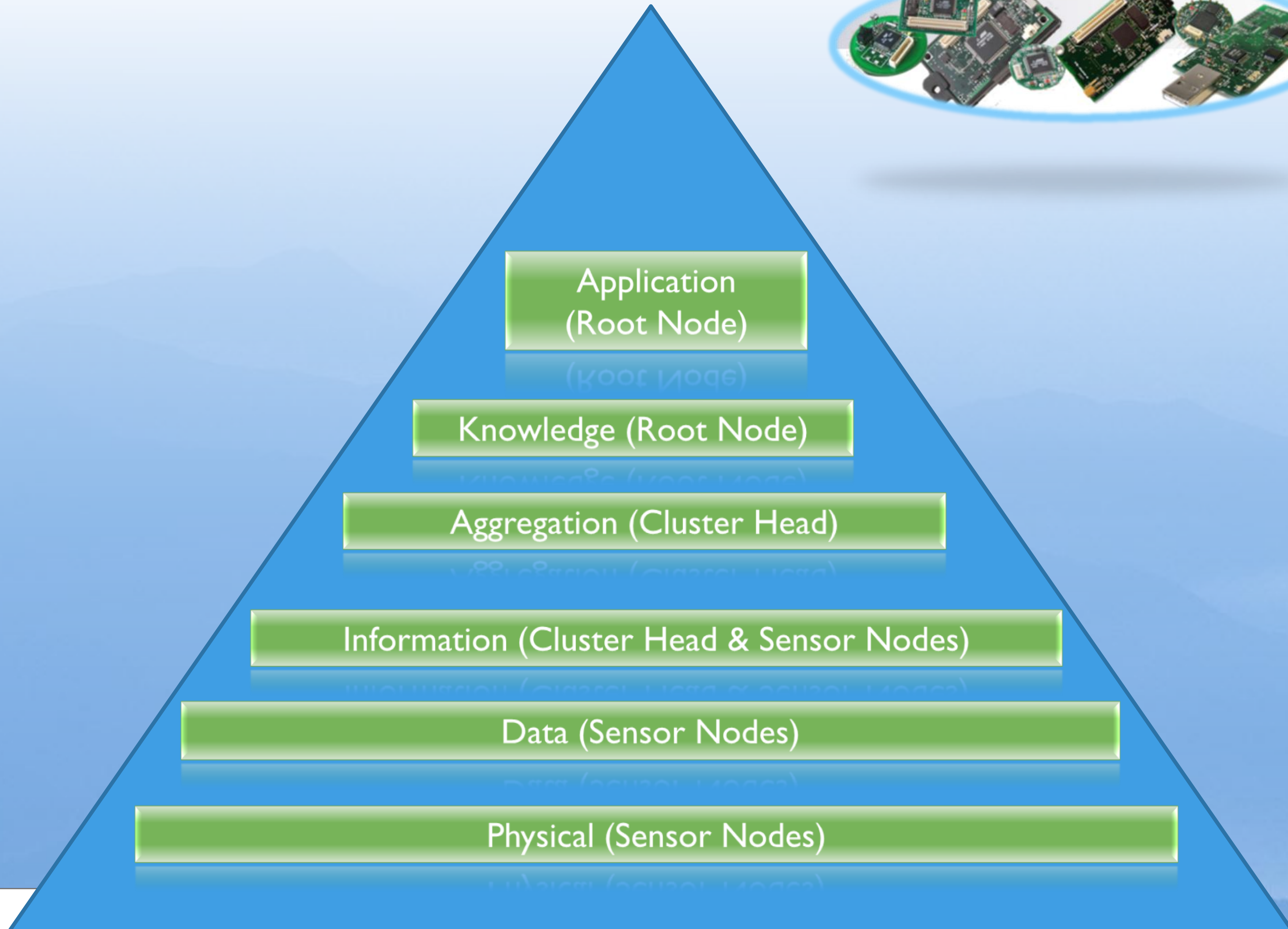
- Defines a layered architecture
  - high-level goal definition to task execution.
- Manages how and where the data is collected.


Application
(Root Node)
Validation (Root Node)
Translation (Cluster Head)
Distribution (Cluster Head & Sensor Nodes)
Execution (Sensor Nodes)
Physical (Sensor Nodes)

Information-Centric Technical Reference Model

- Defines a layered architecture
  - data collection
  - information aggregation
  - presentation
- Not how and where the data is collected.



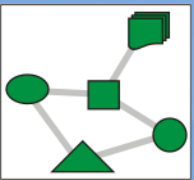


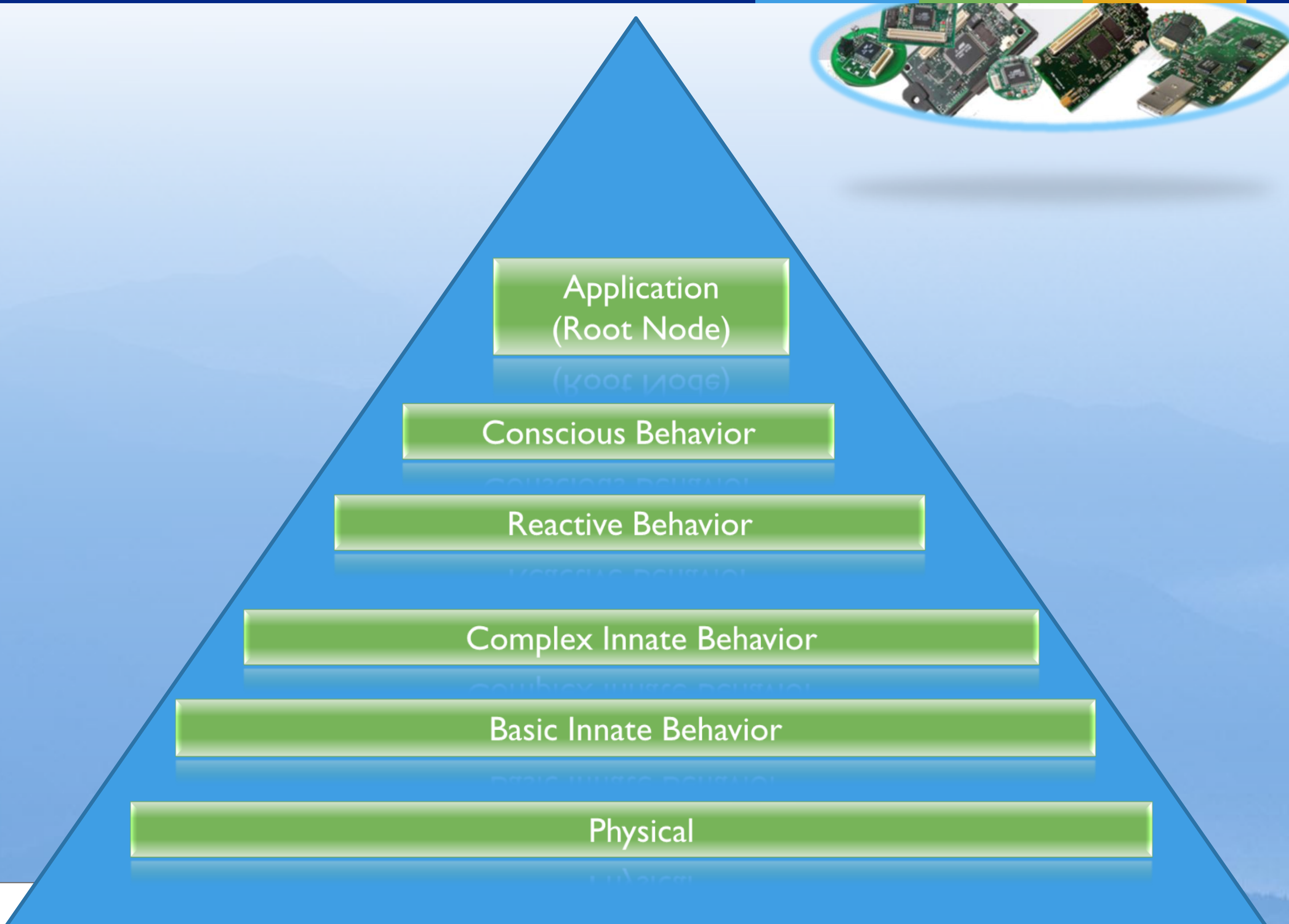
Application
(Root Node)
Knowledge (Root Node)
Aggregation (Cluster Head)
Information (Cluster Head & Sensor Nodes)
Data (Sensor Nodes)
Physical (Sensor Nodes)

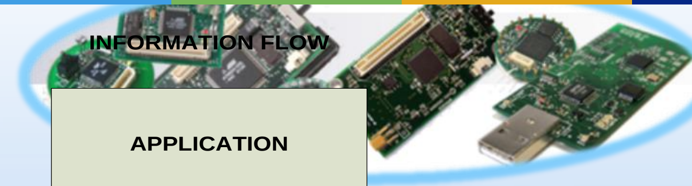
The Link between the Information Processing and Control Mechanisms

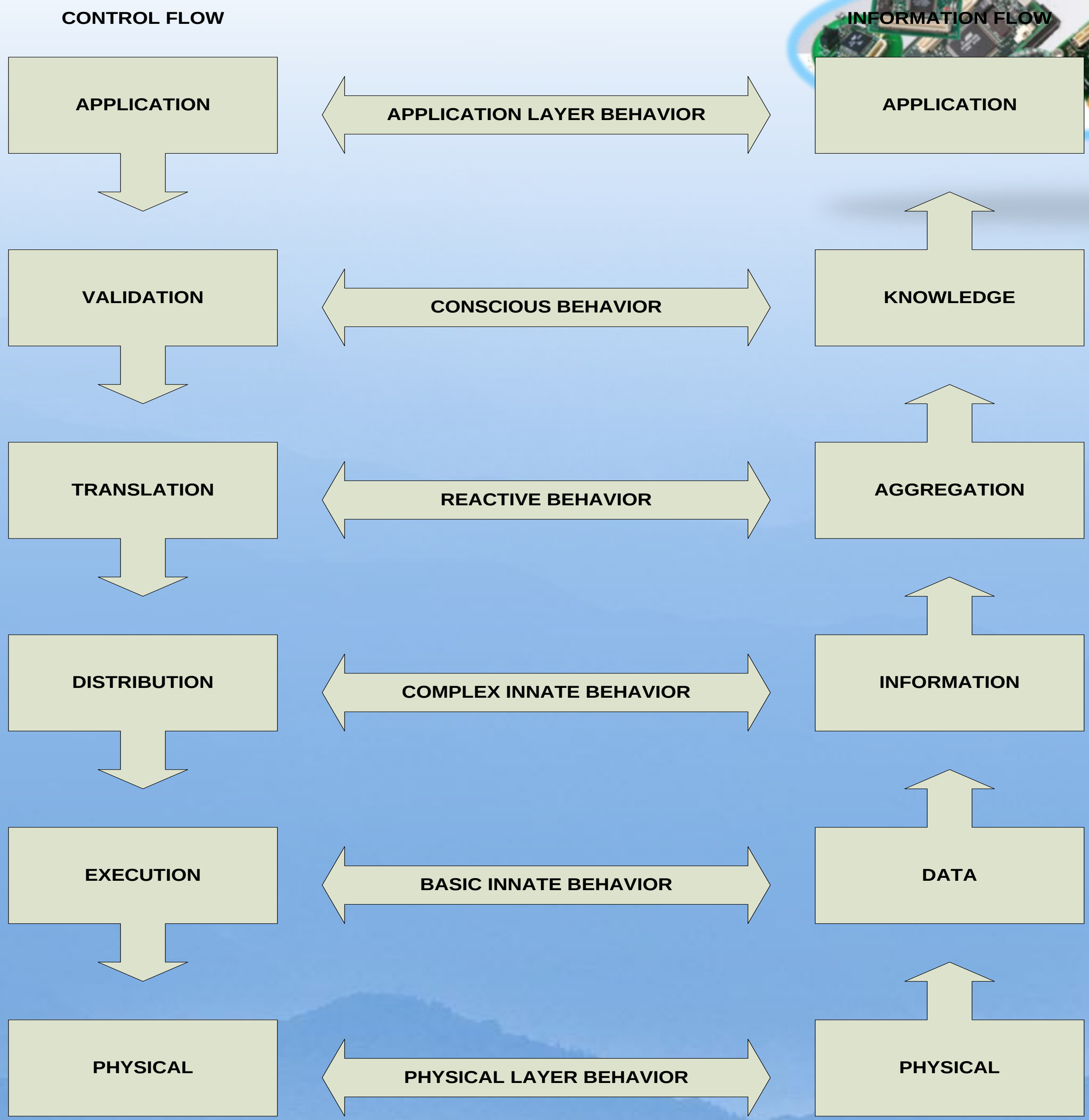
Behavior is:

- A mapping of sensory inputs to a pattern of motor/component actions which then are used to achieve a task.
- The action or reaction of something under specified circumstances.
- A series of events resulting from the execution of the operating rules of that system, as defined within rule-clusters.




Application
(Root Node)
Conscious Behavior
Reactive Behavior
Complex Innate Behavior
Basic Innate Behavior
Physical




CONTROL FLOW
INFORMATION FLOW
APPLICATION
APPLICATION LAYER BEHAVIOR
APPLICATION
VALIDATION
CONSCIOUS BEHAVIOR
KNOWLEDGE
TRANSLATION
REACTIVE BEHAVIOR
AGGREGATION
DISTRIBUTION
COMPLEX INNATE BEHAVIOR
INFORMATION
EXECUTION
BASIC INNATE BEHAVIOR
DATA
PHYSICAL
PHYSICAL LAYER BEHAVIOR
PHYSICAL

Physical Layer:

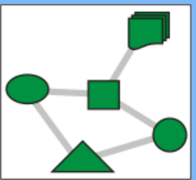
Metadata	Description
Type	Sensor type (e.g. temperature)
Manufacturer	Sensor manufacturer
Model	Sensor model name
Sample size	The size of the generated sample
Sample type	The type of sample (e.g. integer)
AD resolution	A/D resolution (Number of bits)
Sample rate	The sample rate (per second)
Sample rate divider	1 if per second, other int (10, 100…) for slower rates
Location	Location of sensor
Calibration Status	Calibrated or not
Last Calibration Date	Numeric form of "yyyy-mm-dd hh:mm:ss"

- This layer constitutes sensors and mechanical units.
- It gathers raw data in unformatted, unverified and transitory format.
- It deals with the electrical, mechanical and procedural characteristics.
- Metadata associated with the physical layer would be the sensor type, serial number, location, and calibration status.

Data Layer

Metadata	Description
Measurement_ID	Unique identified for this measurement group (e.g. temperature, humidity, pressure1, pressure2, …)
Time Tag	Time tag of sample taken: Numerical form of "yyyy-mm-dd hh:mm:ss:zzz"
Filter Cutoff Frequency	Where applicable, the cut off frequency of the low pass filter
Amplifier Gain	Where applicable, the amplifier gain of the amplifier after the ADC

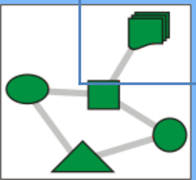
- This layer extracts and transforms data into digital forms and checks the authenticity of the measurements.
- The voltage from the physical layer is transformed into a byte or a word using a proscribed (although possibly variable) process involving amplifiers, filters and analog to digital converters.
- Variable parameters could include sampling rate, digitization accuracy, filter cutoff frequency, amplifier gain, etc.
- Meta-data generated at this level could include these parameters, plus a time tag, a verification bit to indicate that the sensor is calibrated and operating properly, etc. Meta-data from the physical layer and data layer would be bundled with the data to form an informative data packet.



Information Layer:

Information	Description
Measurement ID	Unique identified for this measurement group (e.g. temperature, humidity, pressure1, pressure2, …)
Sensor Data	Actual sensor data obtained from layer 2
Layer 1 Metadata	Optional Field
Layer 2 Metadata	Optional Field
Confidence Level	enum (High, Med, Low) This is obtained by a sliding scale of date of last calibration as well as other environmental factors that may affect performance of the sensor. Details of decision thresholds are implementation specific.

- The third layer correlates data with scaling, location, type of measurement, etc, to produce information about the system or environment.
- The data and metadata from the data layer would be combined to produce information that reports, for example, the temperature at the 12 O'clock position in the combustion chamber of the number one engine was 1000°F at T+1.0 seconds from test start, and that this measurement should be believed with a high degree of confidence.



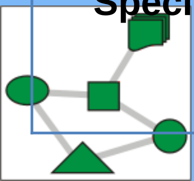
Aggregation Layer:

- The fourth layer is focused on goal-directed merging of information from various sources, as directed by the requirements of the system or subsystem.
- For example, readings from multiple temperature sensors, with synchronized time-tags, could be combined to give an instantaneous view of the temperature gradients within the combustion chamber.
- Additionally, a moving window of a time-sequenced series of readings could be combined to provide the dynamic response to changes in the system. Temperatures, pressures and fuel flows could be combined to create a measure of engine efficiency.

Aggregation Layer:

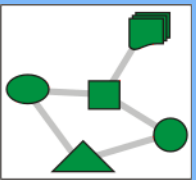
Metadata	Description
Measurement_ID	Unique identified for this measurement group (e.g. temperature, humidity, pressure1, pressure2, …)
General Method	General approach taken to reduce the data. This is from an enumerated list.
Specific Method	The specific method of data reduction employed. For example, for aggregation we can have average, min, max, …
Specific Parameters	This field identifies the parameters and constraints of each specific method used in data reduction in this layer

- The API for this layer is a set of reported outcomes, based on the particular data fusion, estimation or aggregation method specified in the C-TRM API to this layer.
- For example if the C-TRM (control face of the I-TRM) layer had requested a data aggregation by taking the moving average of the last N samples and reporting only the average, this API would report the data and the metadata which precisely identifies the meaning and method of derivation of the reported data.



Knowledge Layer:

- This later transforms aggregated information into knowledge by processing against intrinsic and extrinsic information and knowledge available.
- If the engine temperature approached or exceeded this value, warnings could be issued, or commands could be issued to lower layers in the T&E system to increase sampling rate or accuracy of the engine temperature sensors so a more accurate post-test analysis could be conducted.



Knowledge Layer:

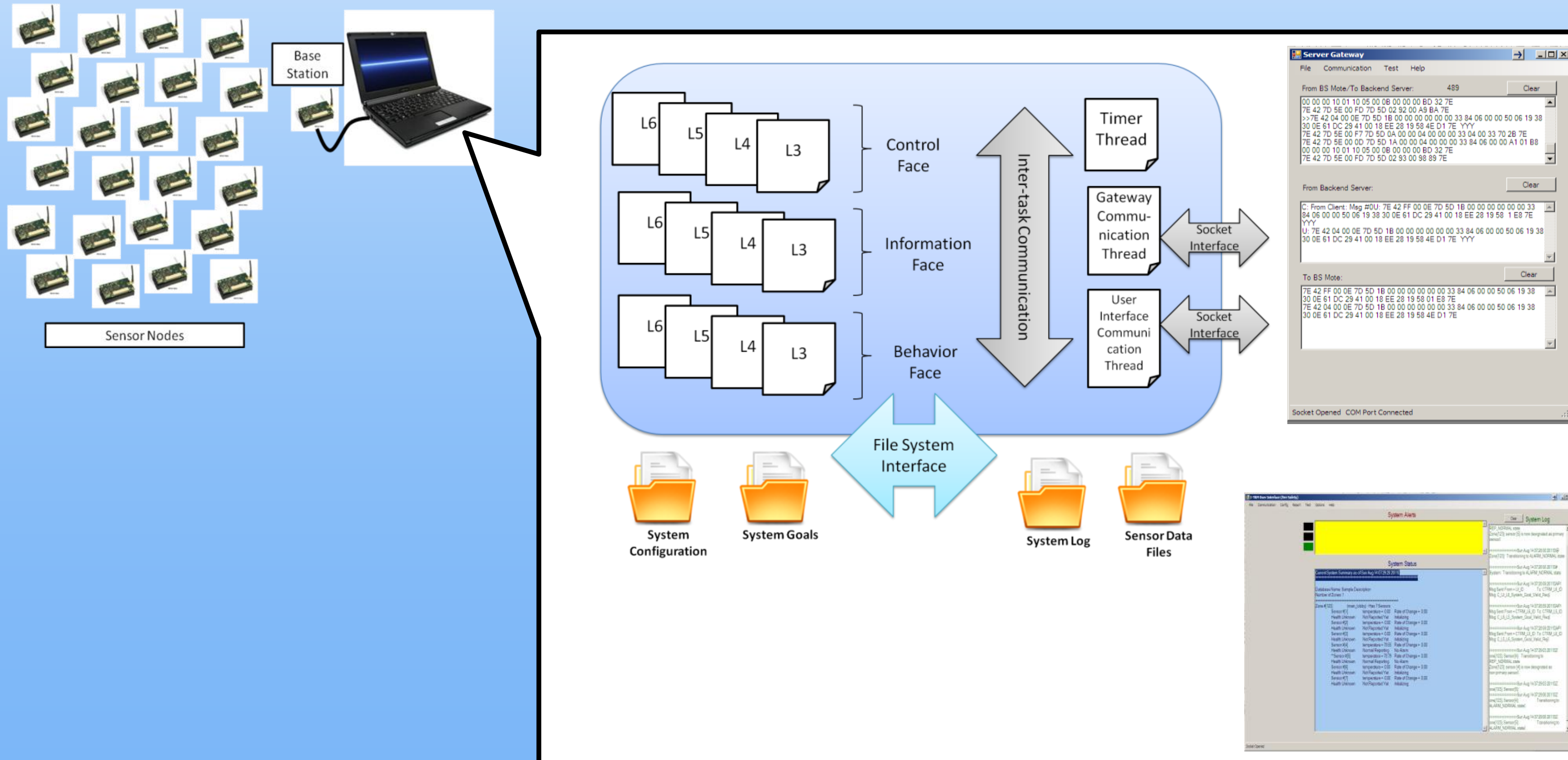
Rule List	Rule Types
IC_L5_Event_Report	enum { Average_Exceeded, StdDev_Exceeded, Trend_Alarm, Activity_Start_Detected, Other } ICTRM_L5_Rule_List_t;

- The knowledge extraction can be in the form of any of the following rules. Additional rules can be added to this layer per specific application implementation.
- Average value for a subset of sensors has exceeded a certain threshold (re-active)
- The variance (or standard deviation) for a subset of sensors has exceeded a certain threshold – indicating an unstable sensor or sensors (re-active)
- The trend in the last N samples is upwards/downwards, towards an alarming threshold (pro-active)
- Data collected indicates detection of start of an “activity” and thereby requiring change in measurement parameters or engaging additional sensors/mechanisms (pro-active)

Application/Presentation Layer:

- The uppermost layer provides a means for the user to access and use information from the system in a consistent format.
- All event reports of layer 5 are made available to the applications via this layer. This layer will provide a universal and standard interface to all applications.

Implementation



Conclusion

- As has been shown partially in this paper the I-TRM API is platform independent as well as application agnostic. It can easily adapt to any application by customizing the data structure containing the application specific parameters passing its address to the pointer in the API calls.
- Very much like the pthreads and other standardized API, the inner workings of the API are abstracted away from the callers, with one major difference that here the inner workings are NOT implemented only once, but are developed for each custom application.
- The positive and negative impacts of this API on a system performance are for future study once a full implementation of the system is available.

QUESTIONS?