# Power Management on the Generic Access Platform

A Technical Paper prepared for SCTE•ISBE by

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# 1. Introduction

Specification of the Generic Access Platform is currently underway (Summer 2020) within SCTE, with broad participation of cable operator and vendor communities. In addition to the requirements for modularity and flexibility driving the effort, the platform will offer unprecedented communications to monitor and control the device and power management is an important feature in those communications.

The cable access network accounts for the vast majority of energy consumed by cable broadband providers, due to the very large number of devices in the outside plant. Measuring energy consumption deep into the network provides a number of business and customer-facing benefits, and the possibility of optimizing electrical usage under certain scenarios offers a glimpse of a more energy efficient, cost efficient, and reliable network.

This paper will briefly introduce GAP and the network configuration (NETCONF) protocol used for its communications, and dive into the SCTE-216 APSIS standard that will provide the power management facilities. APSIS - the Adaptive Power Systems Interface Specification has been developed by the cable operator community and published by the SCTE to provide a comprehensive and flexible data model to represent energy metrics and controls. By adopting a standard data model, costs can be driven out of the data supply chain, and this data can be merged across multiple platforms. A number of APSIS based energy use cases have been developed by the industry, many of which can be directly supported by GAP.

Finally, some suggestions for next steps for the industry will be outlined.

# 2. Power measurement and management on the Generic Access Platform

## 2.1. System Overview

The Generic Access Platform (GAP) is a set of specifications that will be published by SCTE that define interfaces to enable outside plant/access network components from multiple vendors to interoperate to provide a configurable set of functionalities. Unlike a traditional node that embodies a fixed set of features, a GAP chassis can be populated by sub-modules to provide a range of capabilities, and can be updated and reconfigured while in the field. GAP can support any mix of services such as DOCSIS, WiFi, PON, and 5G.

 

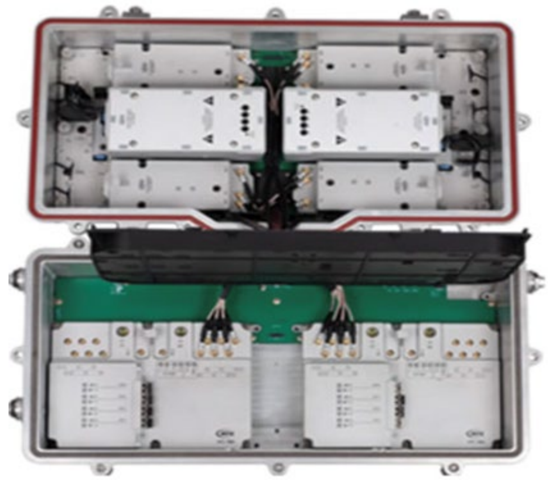

**Figure 1 - GAP**

For more detailed information about GAP, please see the SCTE online description of GAP.

Interoperability demands standardization so that the same type of component supplied by two manufacturers can appear to behave identically to other components in the system. GAP defines how sub-components within a device, such as amplifier, power supply, virtual Cable Modem Termination System (vCMTS) and other components interface with the device chassis. Additionally, GAP defines how the system communicates with an external control component, described as a node manager.

The node manager communicates with the GAP from the head end or other location in the broadband network via the NETCONF protocol.

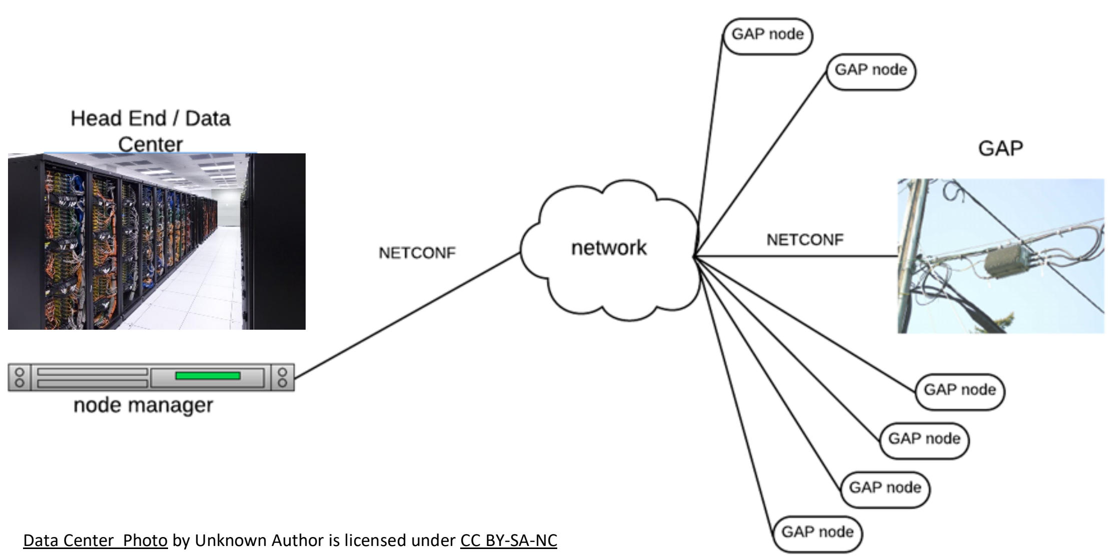


**Figure 2 - System Overview**

 

GAP specifications do not define elements outside the scope of the GAP device and its communications with a node manager, but implicit in the design are applications that make use of the node manager to configure and monitor a population of GAP devices. Applications can interoperate with multiple domains because GAP interfaces are well-specified. - For example, an application that listens to the node manager to detect a power outage on a set of GAP device could be leveraged across multiple cable operators. This 'write-once, run anywhere' facility can greatly speed innovation and reduce prices where it matters - in the development of the sophisticated logic that exists in applications. Even where applications are developed for a specific provider, the use of standards provides a 'loose-coupling' between application logic and the interfaces and data that feed them, reducing development time and maintenance costs. We discuss applications in more detail below.

## 2.2. Node Manager<->GAP Communications

The GAP communications drafting group has begun listing node level management objects that a node manager can monitor. These are in addition to sub-modules specific telemetry. The initial list includes categories for power, inventory, environmental, security, and other sensors.

There are numerous protocols that could be used for node manager to GAP communications. The communications protocol has to be bi-directional, support a rich data set, be fairly low-latency, and support high volume on the node manager side, as one manager may connect to a high quantity of GAP devices. While traditional legacy SNMP might have been selected, modern protocols are more efficient, secure, and easy to use. Of the possible candidates NETCONF was chosen because it meets all of the requirements and has a healthy ecosystem of tooling available.

The NETCONF protocol has been designed specifically for networking applications and is widely supported in routers, switches, and other networking gear. NETCONF messages are described using a formal DSL (Domain Specific Language) called YANG (Yet Another Next Generation). YANG is a human readable text format that can express hierarchical data trees (similar in some ways to an SNMP MIB), remote procedure calls (RPCs) and notifications.

```
container eoDevices {
    config false;
    list eoDevice {
        config false;
        key "id";
        leaf id {type int32;}
        leaf eocategory {
            config false;
            type enumeration {
                enum PRODUCER {description "energy object category";}
                enum CONSUMER {description "energy object category";}
                enum METER {description "energy object category";}
                enum DISTRIBUTOR {description "energy object category";}
                enum STORE {description "energy object category";}
            }
            description "energy object category";
        }
        uses energyGroup;
        container powerInterfaces {
            list powerInterface {
                key "id";
                leaf id {type int32;}
                uses energyGroup;
                description "collection of power interfaces";
            }
        }
        container components {
            list component {
                key "id";
                leaf id {type int32;}
                uses energyGroup;
                description "collection of components";
            }
        }
    }
    description "root of enam api";
}
```

**Figure 3 - YANG snippet**

Tooling is available to auto-generate NETCONF interfaces based on YANG, and to generate complementary RESTCONF interfaces. Where NETCONF is a low-level device oriented protocol, with support for connections and transactions, RESTCONF presents a more application friendly HTTP RESTful API.

In typical NETCONF usage, a software defined networking (SDN) ‘controller’ sits between a service provider’s business applications and networking elements; presenting an easy to use RESTCONF API “northbound” to applications and handling the complexities of interacting with devices via NETCONF on “southbound” interfaces. In the GAP scenario, a node manager embodies the functions of an SDN controller.

## 2.3. APSIS

One of the initial efforts within the SCTE Energy 2020 initiative was to define software interfaces to measure and manage power. A working group was formed to develop the Adaptive Power Systems Interface Specification, or APSIS. Since engineers often like to borrow the work of others rather than build from scratch, a survey of existing power related standards was conducted. The Internet Engineering Task Force (IETF) Energy Management (EMAN) framework was selected as a basis from which APSIS could evolve. Originally defined as a collection of SNMP (Simple Network Management Protocol) MIBs (Management Information Base) contributed by Cisco’s EnergyWise team, EMAN provides a comprehensive and flexible data model for characterizing the power consumption, and production, of any sort of system. The EMAN structure applies well to the cable domain as it can describe a device with any number and configuration of sub-components (like GAP) and can be easily extended to accommodate special cases if the need were to arise. While the APSIS data model is fairly large, specific use cases need only utilize the portions that are relevant in their context.

After selecting IETF EMAN, the APSIS team developed a high-level, protocol independent Information Model and contributed it back to the IETF. The Information Model describes, in Universal Modeling Language (UML), the same data as encoded in the original EMAN MIBS, but in a way that facilitates additional protocol 'bindings'. With this mechanism, teams can develop NETCONF, IPDR, gNMI, or any other style of interface to suit their domain yet be confident that the resulting data can be merged with data sourced using another APSIS compliant protocol.

A protocol independent data model is extremely valuable as we consider the job of processing data at higher logical layers. Consider a predictive modeling application that consumes power data from a wide variety of devices to correlate variables in order to anticipate a service outage - perhaps an unusual oscillation of power quality is a predictor of service failure. If power quality measures are being collected from the widest possible population of sensors, perhaps some using SNMP, some NETCONF off of GAP, some using something else; the modeling application can only reliably utilize that data which is semantically identical, even where the on-the-wire syntax may differ. Where data sources use different models to describe similar things the data quality of the merged set can be unreliable. Data scientists can tell us that even where two differing data source formats use a common key name there is no guarantee the associated values mean the same thing.

By referencing APSIS in the GAP specifications, a reliable data model is established on which to build data processing applications. APSIS can further be adopted by other platforms, either as a native format directly supported by a device, or as a target format for which a defined mapping exists from a non-APSIS or legacy data model in the form of the APSIS model. Another opportunity for expanding the footprint of native APSIS support could be through upcoming revisions to the SCTE power supply/transponder interface specification, SCTE 25-3.

## 2.4. Power Requirements

Among the node manager to GAP communications requirements identified by the GAP working group, a number of power related requirements have been defined, including input voltage, power efficiency, line usage, and power per line, to name a few.

Power consumption is important to proper operations of the access network and it represents a vast majority of electricity costs for a cable provider. As part of the SCTE Energy 2020 program, the cable energy pyramid was published to illustrate the relative energy utilization across portions of a cable operator's footprint.

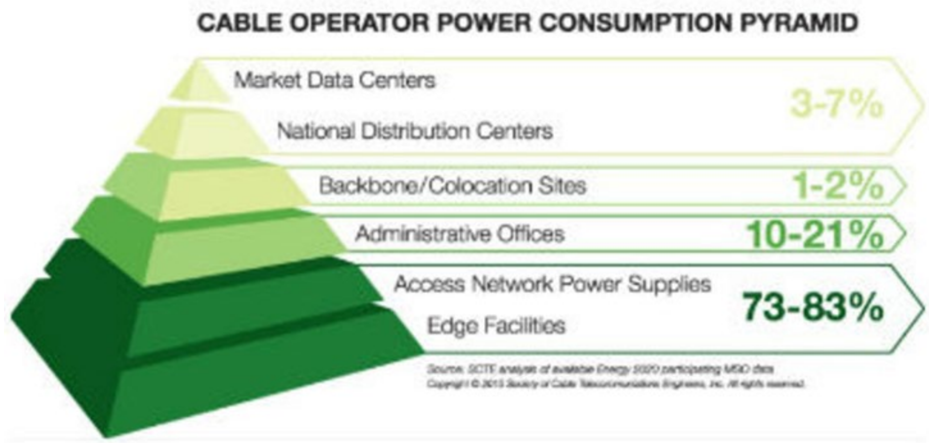


**Figure 4 – SCTE Energy Pyramid**

For a large MSO, the access network alone can consume hundreds of millions of electricity dollars in a year.

## 2.5. Power Use Cases

To this point, little has been done to systematically collect, analyze, or act upon energy data emanating from the access network, outside the scope of individual efforts within some MSOs. By including standardized energy metering and controls into the GAP, MSOs and partners may more cost-effectively build the tooling necessary to fully leverage such data.

A substantial number of use cases pertaining to powering the access network have been articulated by the industry, published as SCTE-245 ‘Use Cases for Adaptive Power Using APSIS’. Use cases have been grouped under several categorizes, including:

- Measurement
- Adaptation
- Demand Response
- Energy Supply monitoring
- Energy Services

As Lord Kelvin stated, "If you cannot measure it, you cannot improve it.” Measurement of energy usage is a fundamental use case. Gaining near-real-time visibility into the sources powering the access network and the power state of components therein supports any number of valuable applications, including at least:

- **Detecting grid power availability.** The cable plant overlays the utility grid and can report with greater resolution the state of power outages. The CableLabs Gridmetrics project is working across the industry to support this and related use cases.
- **Assessing grid power quality.** Grid power is not simply off or on, fluctuations in voltage can impact system performance, reliability, and availability, and can have a dramatic impact on the useful life of equipment.

 

Please refer to SCTE-245 for details on these and many other important use cases.

### 2.6. Adaptive Power

The seed of the APSIS effort was the observation that while cable service demand swings widely between prime-time peak hours and the middle of the night, there is very little corresponding fluctuation in energy usage by the network. The service demand curve is very similar to what's been called the 'duck curve' in the utility industry since the shape of electrical load over the course of a day resembles the silhouette of a duck's back. As cable technologists, the fact that energy consumption remains high when service delivery plunges just feels like a system that is not optimally designed - it's a bit like leaving the lights on when you leave a room at night. The use case of adapting network behavior to correlate energy consumption to the stable and predictable daily service demand oscillation has been labelled 'diurnal adaptation".

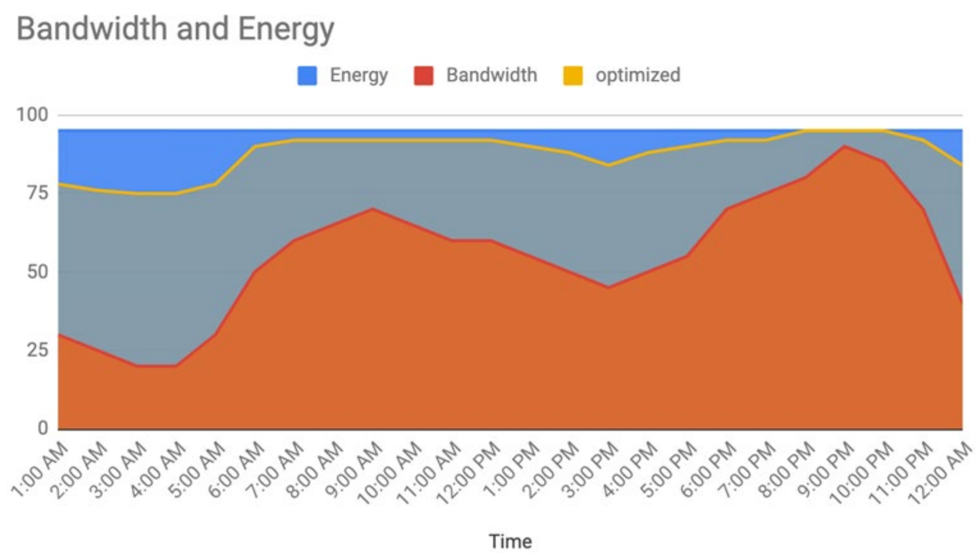


**Figure 5 - Diurnal Adaptation (illustrative)**

Figure 5 attempts to illustrate that the combined blue and grey areas are the flat, unoptimized energy consumption, and the blue is optimized by the effects of diurnal adaptation. The curves do not represent measured data but are simply illustrative of the phenomenon of daily service demand fluctuation and associated energy curves.

Research by vendors, including ARRIS (now CommScope), WES.NET, and Concurrent, demonstrated at earlier SCTE Cable-Tec Expo events, indicate that by carefully managing network resources, daily energy consumption by some networking elements, such as a Converged Cable Access Platform (CCAP), can be reduced by over %15. In the case of CCAP, as data throughput drops below defined thresholds, flows can be remapped to consolidate traffic onto fewer output ports, freeing up line cards that can then be temporarily placed into low power states.

A proof of concept conducted by Comcast with support from ARRIS, also discussed in a previous Cable-Tec Expo, demonstrated the use of APSIS in managing a CCAP to simulate diurnal adaption and confirm the results of earlier prototypes. The open-source OpenDaylight (ODL) SDN controller was selected to act as the control plane, playing a role similar to that of the node manager in the GAP scenario. An EMAN 'plug-in' was developed for ODL to present APSIS as a standardized Northbound API to an energy management application, and a Southbound 'adapter' was developed to integrate with the command line interface (CLI) of the CCAP. A time-lapsed simulation of daily data traffic was fed into a lab installation of a CCAP using the iperf tool, while the energy management application monitored the CCAP to detect the data throughput. When throughput crossed a defined threshold, the application sent commands, via APSIS APIs, through the controller to the device to remap flows and power up/down line cards, as the volume of traffic dictated.

Adaptive control of the GAP could take several forms, including attenuation of the bias current driving the downstream radio frequency (RF) signal. The strength of the baseline bias signal, on to which service information is encoded and carried, can be correlated to the amount of information that needs to be carried. As data volumes increase and decrease to serve shifting demand, the strength of the baseline bias current could correspondingly attenuate. The strength of the signal is a function of the power used to generate it; therefore, a diminished bias current consumes less electricity. In a generic access platform, bias current might be controlled by the signal generator in response to the current service demand, or an external application that has access to other data sources and predicative models could augment this logic to provide a more timely and accurate control algorithm.

In a production environment, such real-time manipulation of the network could only be attempted with sophisticated control mechanisms. A production diurnal controller application would not only monitor data throughput but would factor in a variety of other metrics to maintain consistent quality of service and preserve the custom experience. An application could monitor customer experience metrics such as packet loss and jitter, and predicative modeling of anticipated data rates generated from Machine Learning agents. In addition, weather events, social events like sports, or other phenomenon that might perturb the historical norm could be factored in. The application would have to implement automatic and manual controls to back-off its optimization operations in order to ensure continuity of service. While this seems futuristic today, as network operations have been successful in maintaining their excellent service availability record by minimizing risks and limiting variables, we can anticipate that as software controls become more sophisticated they will be able to lower costs and increase customer satisfaction while addressing the risks of unintended consequences.

Adaptive control is a type of 'closed-loop automation'; a topic of intense focus within the telecommunications world at large. The dream of self-configuring and self-healing networks is in development today.

## 2.7. The Application Layer

Interface standards provide the plumbing through which data and commands can flow, but interface standards are valuable only in what business logic they support. When we include applications into our system view, we get a three-tiered 'full stack' model: devices at the bottom, node manager/SDN controller in the middle, and applications at the top. GAP is a special case of a more general data ingest/processing/business logic framework, as power related data is just one of a number of data streams that can and should be handled in the same general way. Another way of describing the general case is standards and processing system are the domain of data engineering, and the transformation of data into business intelligence is the domain of data science.

 

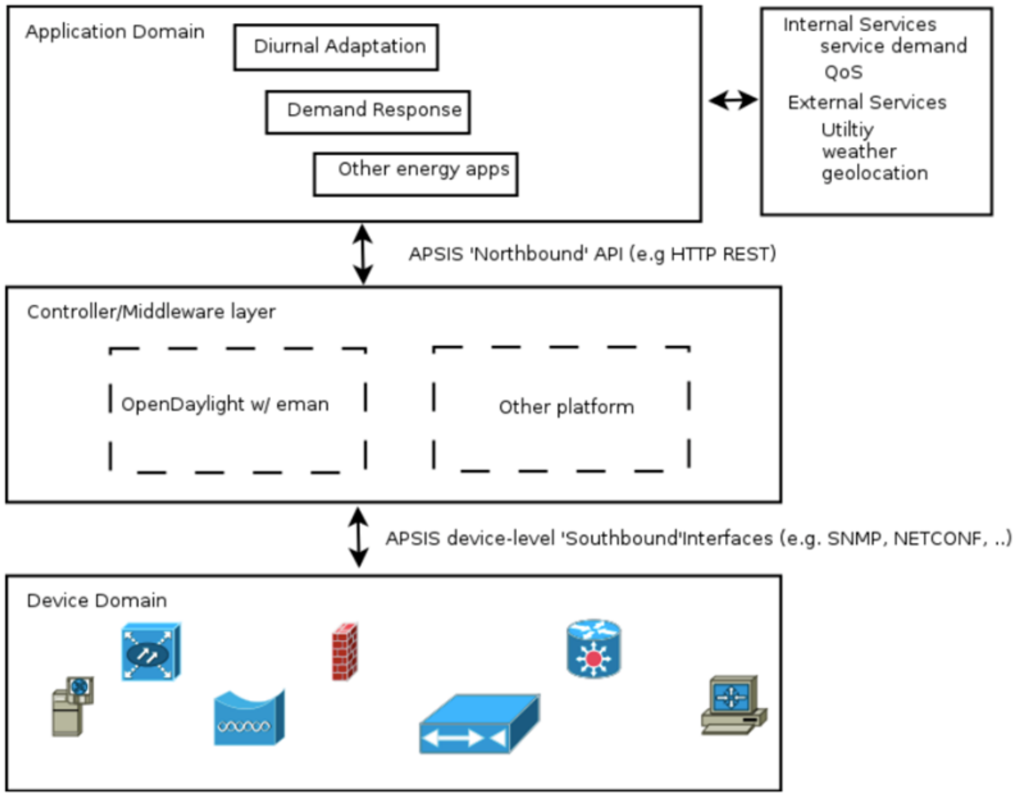


**Figure 6 - Full Stack**

Figure 6 illustrates a general model for a device/controller/application stack. GAP is a specific implementation of this general model, in which the 'Controller' in the node manager and the device domain is limited to GAP.

A healthy ecosystem utilizes standardized data flowing into cable operator data processing systems feeding an ever-growing number of applications. To foster innovation at the application layer, apps must utilize known interfaces and data models - otherwise developers will spend valuable time integrating with bespoke data sources rather than focused on creating valuable business logic.

Cable operators will use their in-house teams to develop some applications, but may also partner with application vendors (exporting data under strict privacy and security controls to authorized and authenticated partners), among whom might include value-added analytics services, utilities, industry consortia, researchers, and any other partner an operator wishes to engage.

## 2.8. Next Steps

Writing and publishing a standard is only worthwhile if it is adopted by multiple industry actors and lead to the creation of business value as previously mentioned in section 2.7. We can greatly speed adoption by performing activities above and beyond simply writing things down on a piece of (virtual) paper and posting it on the web.

The Java Community Process (JCP) provides a great example. A new Java API standard is not considered complete until three deliverables are made available: a specification, a Reference Implementation (RI), and a Technology Compatibility Kit (TCK), or test kit.

 

We might collaborate across the industry to develop a simple prototype of a node manager linked to a GAP simulator to serve as a first-generation Reference Implementation and make API calls to the RI to serve as the beginnings of a test suite.

Because GAP is using NETCONF, our initial prototyping would be quite easy. An NETCONF open-source SDN controller, such as OpenDaylight, could act as a Node Manager, and one of several NETCONF server simulators could present itself as a GAP, by serving up GAP YANG models. A couple of net-conf simulators are: ODL netconf testtool and ntsim.

With a working environment programmers and integrators can then begin to develop application prototypes to learn how best to process, analyze, and act upon GAP data, regardless of whether power related data or other GAP data. The value of an accurate simulation environment cannot be understated for application development - the key is having a system that supports very tight incremental code changes, e.g. tweak/modify a line of code, test it, repeat forever.

The GAP RI could be run on a laptop or could scale up in the cloud. If someone were to donate cloud resources, like a small AWS environment, the industry could share a ‘GAP lab’ to co-develop the RI, tests, and applications.

Finally, the adoption of APSIS by every platform that contributes to power monitoring or controls will drive costs out of developing data pipelines and applications that make use of power data. Think of plumbing a house. If: the sizes of pipes and fittings were all different, made up on the fly, changing from manufacture to manufacturer, and even changing between years and product lines from a single supplier, all of these factors could cause enormous costs and complexity to the modern day homeowner. This indeed was the case in the early days on modern plumbing. Let’s not waste time and money pursuing non-standard solutions to data formats, including power data.

## 3. Conclusion

The Generic Access Platform promises an important evolution in access network technology by establishing a modular and configurable node architecture. Among the many benefits to operators is much improved visibility and control, including power measurement and management. GAP should incorporate the NETCONF protocol for communications with an upstream node manager, driven by well specified data models in the YANG format. For the power components of the communications platform, the SCTE APSIS specification provides an excellent solution as it defines a multi-protocol information model and a YANG binding to provide a comprehensive power measurement and management interface.

As a specification of GAP continues, we call for multi-party collaboration to develop a lightweight prototype implementation to ‘burn in’ the spec and identify gaps or mistakes in the written specification, and to provide an application development platform to generate tests and to research commercially valuable applications that process GAP data and support business value.

Finally, we encourage the adoption of APSIS for all power related interfaces and applications throughout the industry. There is little justification to re-invent a wheel and generating data in differing and potentially incompatible formats will only limit opportunities in deriving the utmost value in power data. Data, like social networks, can exploit ‘network effects’ to increase in value as they are merged and correlated with other data.

 

# Abbreviations

| | |
|---|---|
| 5G | Fifth-Generation cellular wireless |
| API | Application Programming Interface |
| APSIS | Adaptive Power Systems Interface Specification |
| AWS | Amazon Web Services |
| CCAP | Converged Cable Access Platform |
| CLI | Command Line Interface |
| DOCSIS | Data Over Cable Service Interface Specification |
| DSL | Domain Specific Language |
| EMAN | Energy Management |
| HTTP | HyperText Transfer Protocol |
| GAP | Generic access platform |
| IETF | Internet Engineering Task Force |
| ISBE | International Society of Broadband Experts |
| JCP | Java Community Process |
| MIB | Management Information Base |
| MSO | Multiple System Operator |
| NETCONF | Network Configuration |
| ODL | OpenDaylight |
| PON | Passive Optical Network |
| RI | Reference Implementation |
| RESTCONF | RESTful Configuration |
| RF | radio frequency |
| RI | Reference Implementation |
| RPC | Remote Procedure Call |
| SCTE | Society of Cable Telecommunications Engineers |
| SDN | Software Defined Networking |
| SNMP | Simple Network Management Protocol |
| TCK | Technology Compatibility Kit |
| UML | Universal Modeling Language |
| vCMTS | virtual Cable Modem Termination System |
| WiFi | Wireless Fidelity |
| YANG | Yet Another Next Generation |

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RFC7326: Energy Management Framework; Internet Engineering Task Force

RFC6241: NETCONF Network Configuration protocol; Internet Engineering Task Force

RFC7950: YANG Network Configuration protocol; Internet Engineering Task Force

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