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Equipment Capability Application
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Abstract

This document applies the generalized capability principles to the description of equipment (a physical thing) with applied data (configuration state and code (software, firmware etc.)) and shows how such capability specifications integrate with base inventory and entitlement models as defined in Network Inventory, Software Extension and Entitlement YANG models.

The approach is examined by example, focusing on how the potential capabilities of each equipment type-version with applied data are described, how these map to entitlements (licensed or policy-controlled subsets of capabilities), and how they are instantiated as inventory items. The explanation covers both the capabilities of equipment in terms of physical properties and the capabilities of equipment with applied data in terms of resultant emergent functionality.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at https://github.com/marisolpalmero/draft-ietf-davis-generalized-capability-principles/blob/main/draft-davis-ivy-equipment-capability-application-latest.md. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-davis-ivy-equipment-capability-application/.

Discussion of this document takes place on the Network Inventory YANG WG Working Group mailing list (mailto:inventory-yang@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/inventory-yang/. Subscribe at https://www.ietf.org/mailman/listinfo/inventory-yang/.

Source for this draft and an issue tracker can be found at https://github.com/marisolpalmero/draft-ietf-davis-generalized-capability-principles.

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1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT" "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in the document are to be interpreted as described in RFC2119}}.

The following terms abbreviations are used in this document:

* equipment: A physical item necessary for a particular purpose.

* physical: Has spatial dimensions (i.e., can be measured with a "ruler") and in some cases has mass (i.e., can be weighed with scales)

* SFP: Small Form-factor Pluggable which is a category of Equipment

* equipment with applied data: A physical item with compatible software, firmware, configuration etc.

* equipment type-version: A reference to a definition of the

capabilities of an equipment such that all instances of equipment of that type-version have the same capabilities.

2. Introduction

Physical things have various fundamental properties such as length, temperature, weight. In an assembly of physical things each thing plays various roles in the structure and has to be compatible with the other things in that structure so that it can participate in those roles.

In a network operations environment, there are many physical things that support the provision of service. For simplicity, in this document a physical thing that is useful for the provision of network service will be referred to as an equipment. The focus of this document is limited to telecommunications networks and hence equipments for related purposes, but there is no specific limitation to the method that prevent it from being applied more broadly. This restriction is simply to reduce the volume and complexity of the descriptions.

The equipments to be represented include boards (circuit packs) and shelves (subracks). In this description an SFP will be considered as a board and hence an equipment. The essential structural model is that a shelf can be placed in a rack, a board in a slot in a shelf and a board (SFP) in a slot in a board.

Whilst this general model says a board can be placed in a slot, clearly not all boards can be placed in all slots. This document describes the opportunities in terms of physical capabilities of an equipment type-version where all relevant characteristics are the same for each instance of that type-version such that the instances are interchangeable.

Many equipments can accommodate applied data. The desired functionality is emergent from the combination of that equipment with applied data. The statement of capability covers the equipment with applied data.

This document is part of a suite that includes:

* [GenCapPrin] defines the generalized capability and refinement principles.

* [BaseInventory] defines how equipment occurrences are represented in a network inventory.

* [EntitlementInventory] defines how capability entitlements and licensed functionality are tracked.

Together, these drafts describe a continuous trace:

Capability -> Entitlement -> Inventory -> Realization

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Figure 1: Relationship between Capability, Entitlement, and Inventory

where:

* *Capability* defines what an equipment with applied data _can_ do (its potential);

* *Entitlement* defines what an operator _is allowed_ or _enabled_ to use; and

* *Inventory* records what _actually exists_ and is deployed.

The goal of this draft is to show, by concrete examples, how the generalized capability framework is specialized for equipment with applied data and how that structure integrates with inventory and entitlement data.

From a purely physical perspective, whilst the general model says a board can be placed in a slot, clearly not all boards can be placed in all slots. This document describes the opportunities in terms of physical capabilities of types of equipment.

A majority of equipment can be configured and can have its behaviour define by software etc. The capability, in these cases, is emergent from the combination of the physical structure activated by power and shaped by data. Hence the overall capability specification may be defined by a complex combination of capability specifications.

An equipment supports some specific functionality. Some functions emerge from a combination of equipment. The specification method described here allows the functions that emerge from assemblies of equipment to be described in detail.

The specification of potential emergent functions can be used at various stages of the network lifecycle. The specification of emergent functions allows a purchasing application to determine which particular types of equipment can be acquired and a planning tool to determine how to arrange occurrences of types of equipment in systems and what data to apply to support particular functions prior to the purchase of any equipment.

3. Problem Statement

A network is realized through an assembly of equipments (such as circuit packs, boards, racks, cables etc.), some passive (not directly powered), some active (directly powered) and some running complex software. Each assembly provides some capability that supports the provision of service. Understanding these capabilities in detail and precisely is vital throughout the life of the network.

Whilst an active equipment with applied data may provide an interface that exposes what is available currently, it rarely indicates what is potentially available and when it does this is usually through an ad-hoc mechanism which only conveys a limited view of capability. Clearly, when the equipment is not powered, it is not possible to interrogate it even for this sparse and basic information. Passive equipments cannot be interrogated.

Manufactures of equipment produce instances of types of equipment where each instance of a type is essentially identical with respect to capabilities within an acceptable and understood tolerance. Any instance of a type of equipment is interchangeable with another instance of the same type. There may also be other compatibilities where different types have the same or a superset capability and hence can be used as alternatives.

In practice, managing equipment capabilities in isolation is insufficient. Each capability must be tied to:

* an _entitlement_ indicating whether it is licensed or permitted for use, and

* an _inventory record_ that anchors the capability to a deployed occurrence.

This tri-layer relationship enables operators to reason about what equipment types exist, what functions they can theoretically perform, what data needs to be applied to cause these functions to be performed, what has been purchased or activated, and what is currently deployed or configured.

Without such linkage, automation frameworks cannot determine whether a planned configuration is feasible, legally licensed, or available in the installed base.

It is necessary to understand some aspects of capability of a type of equipment with applied data at all stages of the lifecycle:

* whilst speculation about services to be provided prior to network design and researching potential network capabilities

* when planning network structure

* prior to purchasing, when choosing particular equipment types, software etc. for a specific purpose where there are alternatives

* when planning future deployment of equipments, software etc.

* when the equipment is installed and services are being designed

* even when the equipment is fully configured and operational with no errors etc., there may be heartbeat and status capabilities.

Considering the above, it is necessary to have a complete description of capability that is available independent of the presence of equipment etc. This description needs to be rigorous and readily interpretable allowing for comparisons with other equipment types etc. On that basis the capabilities should be described in a normalized language where advantage is taken of recurring patterns etc.

As automation progresses, machine interpretability of the capability information becomes increasingly important. Whilst AI, especially LLMs, can deal with the variety and ambiguity of human languages, a more coherent and compact language usage is preferable for efficiency and removal of potential ambiguity.

This document sets out an approach for expression of capabilities of equipment in terms of physical structure, data structure (software etc.) and emergent functionality.

Whilst knowing the YANG model for the equipment is beneficial, it is not sufficient. The YANG model essentially provides a space within which actual state and configuration can be expresses. The YANG model tends to not express equipment type based constraints. Whilst specifying the combinatorial effects of interacting equipments and software in YANG is potentially possible, the mechanisms available are not designed for this purpose and the results would probably be a large set of special models with extremely cumbersome/complex definitions that would be distinct from the interface model that is necessarily open and broad.

4. Specification in terms of the Model

The specification of capability of equipment with applied data should be presented in terms of the _generalized capability model_ from [GenCapPrin] and explicitly mapped to the inventory and entitlement contexts.

The relationships between these elements can be summarized as:

Concept	Defined In	Represents
Capability Spec	[GenCapPrin], this draft	The potential functions and limits of an equipment type
Entitlement	[EntitlementInventory]	The subset of capabilities permitted or licensed
Inventory Item	[BaseInventory]	The actual occurrence of an entitled capability in the network

Table 1

This linkage ensures that refinement and occurrence formation have a tangible operational anchor in network management systems.

5. Some specification examples

This section illustrates how equipment capability specifications connect to entitlement and inventory concepts.

Example covering an Optical Transponder:

1. *Generic capability*: an abstract optical transponder supporting multiple modulation formats up to 800 G.

2. *Equipment capability specification*: a vendor-specific model constrained to 400 G operation, defining port, thermal, and power envelopes.

3. *Entitlement*: a software license enabling the 400 G feature set; represented via the entitlement model.

4. *Inventory occurrence*: a deployed device instance that has the entitlement applied and exposes its active capabilities through inventory records.

This recursive narrowing from generic capability to entitled occurrence is achieved through a process of pruning and refactoring and demonstrates how specification refinement is operationally realized.

A physical component when powered gives rise to functionality and hence that component has the capability to provide that function.

The specification of that component describes the functions that it can support. A physical component could support a mechanical function, such as the motor in a fan assembly or a virtual function such as an Ethernet termination point.

In a network operations context the relevant field replaceable physical components are called equipments. A board in a shelf is an equipment. Equipment assemblies support complex functions and those functions can be assembled to provide yet more complex functions.

Digging below the level of the board the same consideration applies recursively.

A transistor, when in an appropriate circuit supports a switcing function, i.e., the function is supported by a system of interconnected components including the transistor and perhaps resistors etc. The transistor itself is a small system with a doped channel (a component), a metal terminal (a component) etc. And this carries on down. The transistor in circuit does not operate across its entire range. The specification of capabilities exceeds the needs. The transistor in circuit performs a switching function in a larger system where this may, through multiple levels of assembly, be a CPU. The CPU has a large specification of capability. The capabilities of a specific type of CPU differ from those of other types of CPU. In a particular application, not all of the capabilities are used. The appication may be an embedded controller. The embedded controller will have a set of capabilities. Not all of these will be used in a particular system application. Etc.

Note that in that description the functions emerged from combinations of physical things. The physical and functional considerations are recursively intertwined... a bit of physical, emergent function, function assembly, physical assembly.

Any particular function requires a motive force, i.e., a supply power, and produces heat. Power required and heat produced are always characteristics of any function.

All function are emergent from powered physical components and all physical capabilities are within the scope of the bounday of physical component general definition. Any real physical component is a very narrow form of the full definition. The specification for a physical component provides the constraints to enable an understanding of the physical component.

An equipment is a narrowing of physical component. The network equipment is highly constrained and described by a specification that will focus on fit and emergent functionality. The specification for the equipment will include a type-version identifier and related to that properties on the physical nature of the equipment such as:

* physical dimensions including size in terms of fit relative to some installation position scheme as well dimensions in meters, kg etc.

* temperature/humidity operational range

* physical compatibility including connector type (either directly or indirectly)

* electrical compatibility including voltages

The specific equipment will give rise to functionality when powered and to do this will require supporting or related functions from other equipments. The equipment may require some applied data such that a combination of the physical thing an the applied data (config, software). The specification for the equipment will identify:

* raw functions in terms of general processing

* emergent functional capabilities and needs in terms of more specific functions such as termination point.

* functional compatibility

* power and thermal considerations per functions

To provide useful and valuable functions equipments are used in assemblies forming systems of equipments. The specifications of the individual equipment units will combine to form system specifications where the system is viewed as a component and is defined in terms of:

* raw functions in terms of general processing

* emergent functional capabilities and needs

* functional compatibilities

* power and thermal considerations per functions

6. Pruning and refactoring achieving recursive narrowing

The structure is repeated recursively where at each level, component functions are pruned and refactored then combined into a system with other components that is then viewed as a component yielding a description of emergent functions provided by the component where those are then pruned and refactored then combined etc.

7. A basic photonic device specification buid up

To make this easier, the description assumes a single equipment with a full implementation of an amplifier being used in a unidirectional context. The amplifier is assumed to have an embedded controller that can communicate via a YANG defined interface to a network controller etc.

The physical equipment has various physical structures present. None are field replaceable so it can be considered as a simple single unit.

The equipment has a type and version. It is equipped with several physical units including several lasers, a length of fiber, a "circulator" and various units of electronics. It also has a microprocessor and assocuates circuitry and physical connectors along with mounting structures. Each of these units give rise to functionality that can be defined in isolation or in small systems.

Some of the physical units have existing specifications. For example each laser will have a specification detailing its power requirements, its spectrum, its thermal requirements etc. It may come equipped with a back diode for monitoring power. It will be installed in a module that has a bias control circuit and monitors. The laser will not be used across its entire range of capability, in fact, being a pump laser it will operate at one very precise point of its operational range.

The pump lasers will be attached to specific points in the fiber. There may be one at either end coupled in via a coupler. The reverse laser will be isolated from the fibre by the circulator.

The detailed specifications will be pruned and refactored through several layers to give rise to the amplifier characteristics such that a component (in some models such as G.7711, this would be represented by a forwarding construct (a connection)) with gain (as opposed to loss) properties with some spectral characteristic.

It is possible to start at any level in this recursive structure with an abstraction of what lies below without deriving the abstraction fully. So it would be reasonable to simply state the highest abstraction on a specification identifying gain characteristics etc. BUT in a more advanced solution detailed derivation would enable a greater opportunity for reasoning across the detail to understand failure modes and subtle behaviours.

It would be optimum to place the power detectors etc. in the detailed model in their precise position with respect to other physical/ optical compoents such that the model can be reasoned across to understand implication of an indication on the functionality of the equipment. However, initially they could be loosely placed at the input or output of the function as a rough projection of their detection position.

In summary, given the right generalized model, it is possible to build specifications. This could start with a simple type-version label and grow over time to a reference to some detail that is in terms of labels that further opens up in later developments. This gradual progression will allow the capability to unfold in value justified steps.

As the process develops and beds in it is expected that specifications will be developed as equipments and developed and LLMs will assist in that development and refinement.

8. A system arrangements for a protection scheme.

From the above it is relatively clear how terminations functions and connections may emerge from underlying hardware and how that can be presented in terms of a specification. A specification for a system arrangement for a service and associated realization pattern specifications.

This general principle is considered in the context of equipment specification.

9. Specification of an assembly

Highlighting this general principle in terms of assemblies of equipment with applied data and the emergent behaviour that results.

10. Generalization of the specification

Showing the reuse of specification fragments.

11. Using the language of specification

This requires work in the generalized capabilities draft.

12. Building the equipment specification structure

Take the language and general structure and build specific equipment.

13. Conclusion

This document applies the generalized capability principles to the specific case of equipment with applied data. By linking equipment capability descriptions to entitlements and inventory items, it creates a complete semantic chain from potential -> permitted -> realized.

This alignment ensures that planning, procurement, licensing, and operational systems can reason coherently about equipment functions and their lifecycle. The approach enables automation, energy- and sustainability-aware network management, and AI-assisted reasoning grounded in formally defined capability structures.

14. Security Considerations

TBD

15. IANA Considerations

This document has no IANA actions.

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Appendix A. Acknowledgments

This document has been made with consensus and contributions coming from multiple drafts with different visions. We would like to thank all the participants in the IETF meeting discussions.

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