Abstract

Intent and Intent-Based Networking are taking the industry by storm. At the same time, those terms are used loosely and often inconsistently, in many cases overlapping with other concepts such as "policy". This document is therefore intended to clarify the concept of "Intent" and how it relates to other concepts. The goal is to contribute towards a common and shared understanding of terms and concepts which can then be used as foundation to guide further definition of valid research and engineering problems and their solutions.

Status of This Memo

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1. Introduction

Traditionally in the IETF, interest with regard to management and operations has focused on individual network and device features. Standardization emphasis has generally been put on management instrumentation that needed to be provided by a networking device. A prime example for this is SNMP-based management and the 200+ MIBs that have been defined by the IETF over the years. More recent examples include YANG data model definitions for aspects such as interface configuration, ACL configuration, or Syslog configuration.

There is a sense that managing networks by configuring myriads of "nerd knobs" on a device-by-device basis is no longer sustainable in modern network environments. Big challenges arise with keeping device configurations not only consistent across a network, but consistent with the needs of services they are supposed to enable. At the same time, operations need to be streamlined and automated wherever possible to not only lower operational expenses, but allow for rapid reconfiguration of networks at sub-second time scales.

Accordingly, IETF has begun to address end-to-end management aspects that go beyond the realm of individual devices in isolation.
Examples include the definition of YANG models for network topology [RFC8345] or the introduction of service models used by service orchestration systems and controllers [RFC8309]. In addition, a lot of interest has been fueled by the discussion about how to manage autonomic networks as discussed in the ANIMA working group. Autonomic networks are driven by the desire to lower operational expenses and make management of the network as a whole exceptionally easy, putting it at odds with the need to manage the network one device and one feature at a time. However, while autonomic networks are intended to exhibit "self-management" properties, they still require input from an operator or outside system to provide operational guidance and information about the goals, purposes, and service instances that the network is to serve. It is in this context that the term "intent" was coined for the first time.

This vision has since caught on with the industry in a big way, leading to countless offerings that tout "intent-based management" that promise network providers to manage networks holistically at a higher level of abstraction and as a system that happens to consist of interconnected components, as opposed to a set of independent devices (that happen to be interconnected). Those offerings include SDN controllers (offering a single point of control and administration for a network) as well as network management and Operations Support Systems (OSS).

However, it has been recognized for a long time that comprehensive management solutions cannot operate only at the level of individual devices and low-level configurations. In this sense, the vision of "intent" is not entirely new. In the past, ITU-T’s model of a Telecommunications Management Network, TMN, introduced a set of management layers that defined a management hierarchy, consisting of network element, network, service, and business management. High-level operational objectives would propagate in top-down fashion from upper to lower layers. The associated abstraction hierarchy was key to decompose management complexity into separate areas of concerns. This abstraction hierarchy was accompanied by an information hierarchy that concerned itself at the lowest level with device-specific information, but that would, at higher layers, include, for example, end-to-end service instances. Similarly, the concept of "policy-based management" has for a long time touted the ability to allow users to manage networks by specifying high-level management policies, with policy systems automatically "rendering" those policies, i.e. breaking them down into low-level configurations and control logic.

What is missing, however, is putting these concepts into a more current context and defining a reference model that goes beyond a TMN. This document attempts to clarify terminology and explain how
intent relates to other, similar concepts, in hope that a common and shared understanding of terms and concepts can be used as a foundation to articulate research and engineering problems and their solutions.

2. Key Words

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Definitions and Acronyms

- ACL: Access Control List
- Intent: An abstract, high-level policy used to operate a network [RFC7575].
- Policy: A rule, or set of rules, that governs the choices in behavior of a system.
- PDP: Policy Decision Point
- PEP: Policy Enforcement Point
- Service Model: A model that represents a service that is provided by a network to a user.

4. Introduction of Concepts

The following subsections provide an overview of the concepts of service models, of policies respectively policy-based management, and of intent respectively intent-based management. While the descriptions are intentionally kept brief and do not provide detailed tutorials, they should convey the bigger picture of the purpose of each concept and provide a sense where those concepts are similar and where they differ. With this background, the differences between them are subsequently summarized in in another section.

4.1. Service Models

A service model is a model that represents a service that is provided by a network to a user. Per [RFC8309], a service model describes a service and its parameters in a portable way that can be used independent of the equipment and operating environment on which the service is realized. Two subcategories are distinguished: a
"Customer Service Model" describes an instance of a service as provided to a customer, possibly associated with a service order. A "Service Delivery Model" describes how a service is instantiated over existing networking infrastructure.

An example of a service could be a Layer 3 VPN service [RFC8299], a Network Slice, or residential Internet access. Service models represent service instances as entities in their own right. Services have their own parameters, actions, and lifecycles. Typically, service instances can be bound to end users, who might be billed for the service.

Instantiating a service typically involves multiple aspects:

- Resources need to be allocated, such as IP addresses, interfaces, bandwidth, or memory.
- How to map services to the resources needs to be defined. Multiple mappings are often possible, which to select may depend on context (such as which type of access is available to connect the end user with the service).
- Bindings need to be maintained between upper- and lower-level objects.

They involve a system, such as a controller, that provides provisioning logic. Orchestration itself is generally conducted using a "push" model, in which the controller/manager initiates the operations as required, pushing down the specific configurations to the device. The device itself typically remains agnostic to the service or the fact that its resources or configurations are part of a service/concept at a higher layer.

Instantiated service models map to instantiated lower-layer network and device models. Examples include instances of paths, or instances of specific port configurations. The service model typically also models dependencies and layering of services over lower-layer networking resources that are used to provide services. This facilitates management by allowing to follow dependencies for troubleshooting activities, to perform impact analysis in which events in the network are assessed regarding their impact on services and customers. Services are typically orchestrated and provisioned top-to-bottom, which also facilitates keeping track of the assignment of network resources.

Service models also associate with other data that does not concern the network but provides business context. This includes things such as customer data (such as billing information), service orders and
service catalogues, tariffs, service contracts, and Service Level Agreements (SLAs) including contractual agreements regarding remediation actions.

4.2. Policy and Policy-Based Management

Policy-based management (PBM) is a management paradigm that separates the rules that govern the behavior of a system from the functionality of the system. It promises to reduce maintenance costs of information and communication systems while improving flexibility and runtime adaptability. It is today present at the heart of a multitude of management architectures and paradigms including SLA-driven, Business-driven, autonomous, adaptive, and self-* management [Boutaba07]. The interested reader is asked to refer to the rich set of existing literature which includes this and many other references. In the following, we an only provide a much-abridged and distilled overview.

At the heart of policy-based management is the concept of a policy. Multiple definitions of policy exist: "Policies are rules governing the choices in behavior of a system" [Sloman94]. "Policy is a set of rules that are used to manage and control the changing and/or maintaining of the state of one or more managed objects" [Strassner03]. Common to most definitions is the definition of a policy as a "rule". Typically, the definition of a rule consists of an event (whose occurrence triggers a rule), a set of conditions (that get assessed and that must be true before any actions are actually "fired"), and finally a set of one or more actions that are carried out when the condition holds.

Policy-based management can be considered an imperative management paradigm: Policies specify precisely what needs to be done when. Using policies, management can in effect be defined as a set of simple control loops. This makes policy-based management a suitable technology to implement autonomic behavior that can exhibit self-* management properties including self-configuration, self-healing, self-optimization, and self-protection. In effect, policies define simple control loops typically used to define management as a set of simple control loops.

Policies typically involve a certain degree of abstraction in order to cope with heterogeneity of networking devices. Rather than having a device-specific policy that defines events, conditions, and actions in terms of device-specific commands, parameters, and data models, policy is defined at a higher-level of abstraction involving a canonical model of systems and devices to which the policy is to be applied. A policy agent on the device subsequently "renders" the policy, i.e., translates the canonical model into a device-specific
representation. This concept allows to apply the same policy across a wide range of devices without needing to define multiple variants. This enables operational scale and allows network operators and authors of policies to think in higher terms of abstraction than device specifics.

Policy-based management is typically "push-based": Policies are pushed onto devices where they are rendered and enforced. The push operations are conducted by a manager or controller, which is responsible for deploying policies across the network and monitor their proper operation. That said, other policy architectures are possible. For example, policy-based management can also include a pull-component in which the decision regarding which action to take is delegated to a so-called Policy Decision Point (PDP). This PDP can reside outside the managed device itself and has typically global visibility and context with which to make policy decisions. Whenever a network device observes an event that is associated with a policy, but lacks the full definition of the policy or the ability to reach a conclusion regarding the expected action, it reaches out to the PDP for a decision (reached, for example, by deciding on an action based on various conditions). Subsequently, the device carries out the decision as returned by the PDP - the device "enforces" the policy and hence acts as a PEP (Policy Enforcement Point). Either way, PBM architectures typically involve a central component from which policies are deployed across the network, and/or policy decisions served.

4.3. Intent and Intent-Based Management

In the context of Autonomic Networks, Intent is defined as "an abstract, high-level policy used to operate a network" [RFC7575]. According to this definition, an intent is a specific type of policy. However, to avoid using "intent" simply as a synonym for "policy, a clearer distinction needs to be introduced that distinguishes intent clearly from other types of policies.

Autonomic networks are expected to "self-manage" and operate with minimal outside intervention. However, autonomic networks are not clairvoyant and have no way of automatically knowing particular operational goals nor what instances of networking services to support. In other words, they do not know what the "intent" of the network provider is that gives the network the purpose of its being. This still needs to be communicated by what informally constitutes "intent".

More specifically, intent is a declaration of high-level operational goals that a network should meet, without specifying how to achieve them. Those goals are defined in a manner that is purely declarative
they specify what to accomplish or what the desired outcome for the
network operator is, not how to achieve it. This encompasses
abstraction from low-level device configurations, as well as
abstraction from particular management and control logic such as when
to spring into action.

In an autonomic network, intent should be rendered by the network
itself, i.e. translated into device specific rules and courses of
action. Ideally, it should not even be orchestrated or broken down
by a higher-level, centralized system, but by the network devices
themselves using a combination of distributed algorithms and local
device abstraction. Because intent holds for the network as a whole,
not individual devices, it needs to be automatically disseminated
across all devices in the network, which can themselves decide
whether they need to act on it. This facilitates management even
further, since it obviates the need for a higher-layer system to
break down and decompose higher-level intent, and because there is no
need to even discover and maintain an inventory of the network to be
able to manage it. Intent thus constitutes declarative policy with a
network-wide scope. A human operator defines ‘what’ is expected, and
the network computes a solution meeting the requirements. This
computation can occur in distributed or even decentralized fashion by
auonomic functions that reside on network nodes.

Other definitions of intent exist such as [TR523] and will be
investigated in future revisions of this document. Likewise, some
definitions of intent allow for the presence of a centralized
function that renders the intent into lower-level policies or
instructions and orchestrates them across the network. While to the
end user the concept of "intent" appears the same regardless of its
method of rendering, this interpretation opens a slippery slope of
how to clearly distinguish "intent" from other higher-layer
abstractions. Again, these notions will be further investigated in
future revisions of this document and in collaboration with NMRG.

5. Distinguishing between Intent, Policy, and Service Models

What Intent, Policy, and Service Models all have in common is the
fact that they involve a higher-layer of abstraction of a network
that does not involve device-specifics, that generally transcends
individual devices, and that makes the network easier to manage for
applications and human users compared to having to manage the network
one device at a time. Beyond that, differences emerge. Service
models have less in common with policy and intent than policy and
intent do with each other.

Summarized differences:
o A service model is a data model that is used to describe instances of services that are provided to customers. A service model has dependencies on lower models (device and network models) when describing how the service is mapped onto underlying network and IT infrastructure. Instantiating a service model requires orchestration by a system; the logic for how to orchestrate/manage/provide the service model and how to map it onto underlying resources is not included as part of the model itself.

o Policy is a set of rules, typically modeled around a variation of events/conditions/actions, used to express simple control loops that can be rendered by devices themselves, without requiring intervention by outside system. Policy is used to define what to do under what circumstances, but it does not specify a desired outcome.

o Intent is a higher-level declarative policy that operates at the level of a network, not individual devices. It is used to define outcomes and high-level operational goals, without the need to enumerate specific events, conditions, and actions. Ideally, intent is rendered by the network itself; also the dissemination of intent across the network and any required coordination between nodes is resolved by the network itself without the need for outside systems.

The TM Forum’s Business Process Framework for network service providers [eTOM] categorizes network operations broadly into three categories: Fulfillment, Assurance, and Billing. Intent is generally tied to fulfillment, broadly defined as all activities and processes having to do with configuration of the network to fulfill a given purpose. It is not tied to assurance, broadly defined as all activities and processes having to do with keeping the network and services running (including monitoring, measuring, reporting, assessing compliance of service levels with service level objectives, diagnostics, etc). Policy, on the other hand, aligns more closely with assurance.

6. Items for Discussion

Arguably, given the popularity of the term intent, its use could be broadened to encompass also known concepts ("intent-washing"). For example, it is conceivable to introduce intent-based terms for various concepts that, although already known, are related to the context of intent. Each of those terms could then designate an intent subcategory, for example:
Operational Intent: defines intent related to operational goals of an operator; corresponds to the original "intent" term.

Rule Intent: a synonym for policy rules regarding what to do when certain events occur.

Service intent: a synonym for customer service model [RFC8309].

Flow Intent: A synonym for a Service Level Objective for a given flow.

Whether to do so is an item for discussion by the Research Group.

7. IANA Considerations

Not applicable

8. Security Considerations

Not applicable

9. References

9.1. Normative References


9.2. Informative References


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Abstract

RFC 7575 [RFC7575] defines Intent as an abstract high-level policy used to operate the network. Intent management system includes an interface for users to input requests and an engine to translate the intents into the network configuration and manage their lifecycle. Up to now, there is no commonly agreed definition, interface or model of intent.

This document discusses what intent means to different stakeholders, describes different ways to classify intent, and an associated taxonomy of this classification.
1. Introduction

Different SDOs (such as [ANIMA][ONF]) have proposed intent as a declarative interface for defining a set of network operations to execute.

Although there is no common definition or model of intent which are agreed by all SDOs, there are several shared principles:

- intent should be declarative, using and depending on as few deployment details as possible and focusing on what and not how
- intent should provide an easy-to-use interface, and use terminology and concepts familiar to its target audience
- intent should be vendor-independent and portable across platforms
- the intent framework should be able to detect and resolve conflicts between multiple intents
SDOs have different perspectives on what intent is, what set of actors it is intended to serve, and how it should be used. This document provides several dimensions to classify intents.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Acronyms

  CLI: Command Line Interface
  SDO: Standards Development Organisation
  SUPA: Simplified Use of Policy Abstractions
  VPN: Virtual Private Network

4. Abstract intent requirements

In order to understand the different intent requirements that would drive intent classification, we first need to understand what intent means for different intent users.

4.1. What is Intent

The term Intent has become very widely used in the industry for different purposes, sometimes it is not even in agreement with SDO shared principles mentioned in the Introduction. Different stakeholders consider an intent to be an ECA policy, a GBP policy, a business policy, a network service, a customer service, a network configuration, application / application group policy, any operator/administrator task, network troubleshooting / diagnostics / test, a new app, a marketing term for existing management/orchestration capabilities, etc. Their intent is sometimes technical, non-technical, abstract or technology specific. For some stakeholders, intent is a subset of these and for other
stakeholders intent is all of these. It has in some cases become a term to replace a very generic ‘service’ or ‘policy’ terminology.

While it is easier for those familiar with different standards to understand what service, CFS, RFS, resource, policy continuum, ECA policy, declarative policy, abstract policy or intent policy is, it may be more difficult for the wider audience. Intent is very often just a synonym for policy. Those familiar with policies understand the difference between a business, intent, declarative, imperative and ECA policy. But maybe the wider audience does not understand the difference and sometimes equates the policy to an ECA policy.

Therefore, it is important to start a discussion in the industry about what intent is for different solutions and intent users. It is also imperative to try to propose some intent categories / classifications that could be understood by a wider audience. This would help us define intent interfaces, DSLs and models.

4.2. Intent Solutions & Intent Users

Different Solutions and Actors have different requirements, expectations and priorities for intent driven networking. They require different intent types and have different use cases. Some users are more technical and require intents that expose more technical information. Other users do not understand networks and require intents that shield them from different networking concepts and technologies.

4.3. Current Problems & Requirements

Network APIs and CLIs are too complex due to the fact that they expose technologies & topologies. App developers and end-users do not want to set IP Addresses, VLANs, subnets, ports, etc. Operators and administrators would also benefit from the simpler interfaces, like:

- Allow Customer Site A to be connected to Internet via Network B
- Allow User A to access all internal resources, except the Server B
- Allow User B to access Internet via Corporate Network A
- Move all Users from Corporate Network A to the Corporate Network B
o Request Gold VPN service between my sites A, B and C
o Provide CE Redundancy for all Customer Sites
o Add Access Rules to my Service

Networks are complex, with many different protocols and encapsulations. Some basic questions are not easy to answer:

o Can User A talk to User B?
o Can Host A talk to Host B?
o Are there any loops in my network?
o Are Network A and Network B connected?
o Can User A listen to communications between Users B & C?

Operators and Administrators manually troubleshoot and fix their networks and services. They instead want:

o a reliable network that is self-configured and self-assured based on the intent
o to be notified about the problem before the user is aware
o automation of network/service recovery based on intent (self-healing, self-optimization)
o to get suggestions about correction/optimization steps based on experience (historical data & behaviour)

Therefore, Operators and Administrators want to:

o simplify and automate network operations
o simplify definitions of network services
o provide simple customer APIs for Value Added Services (operators)
o be informed if the network or service is not behaving as requested
End-Users cannot build their own services and policies without becoming technical experts and they must perform manual maintenance actions. Application developers and end-users/subscribers want to be able to:

- build their own network services with their own policies via simple interfaces, without becoming networking experts
- have their network services up and running based on intent and automation only, without any manual actions or maintenance

4.4. Intent Types that need to be supported

The following intent types need to be supported, in order to address the requirements from different solutions and intent users:

- Customer network service intent
- Network resource management
- Cloud and cloud resource management
- Network Policy intent
- Task based intents
- System policies intents

5. The Policy Continuum

The Policy Continuum defines the set of actors that will create, read, use, and manage policy. Each set of actors has their own terminology and concepts that they are familiar with. This captures the fact that business people do not want to use CLI, and network operations center personnel do not want to use non-technical languages.
6. Functional Characteristics and Behavior

Intent can be used to operate immediately on a target (much like issuing a command), or whenever it is appropriate (e.g., in response to an event). In either case, intent has a number of behaviors that serve to further organize its purpose, as described by the following subsections.

6.1. Persistence

Intents can be classified into transient/persistent intents.

If intent is transient, it has no lifecycle management. As soon as the specified operation is successfully carried out, the intent is finished, and can no longer affect the target object.

If the intent is persistent, it has lifecycle management. Once the intent is successfully activated and deployed, the system will keep all relevant intents active until they are deactivated or removed.

6.2. Granularity

Intents can have different granularities: high granularity, low granularity and anything in between.

High granularity intents are more complex to design but are the most valuable. Intent translation, intent conflict resolution and intent verification are very complex and require advanced algorithms. Examples: end-to-end network service, like customer network service over physical & virtual network, over access, metro, dc and wan with all related QoS, security and application policies.

Low granularity intents, like some path checks (can A talk to B) or individual network service/network/application/user policies, are the least complex. Their intent translation, intent conflict resolution and intent verification are much simpler than for high granularity intents.
6.3. Abstracting Intent Operation

The modeling of Policies can be abstracting using the following three-tuple:

(Context, Capabilities, Constraints)

Context grounds the policy, and determines if it is relevant or not for the current situation. Capabilities describe the functionality that the policy can perform. Capabilities take different forms, depending on the expressivity of the policy as well as the programming paradigm(s) used. Constraints define any restrictions on the capabilities to be used for that particular context. Metadata can be optionally attached to each of the elements of the three-tuple, and may be used to describe how the policy should be used and how it operates, as well as prescribe any operational dependencies that must be taken into account.

Put another way:

- Context selects policies based on applicability
- Capabilities describe the functionality provided by the policy
- Constraints restrict the capabilities offered and/or the behavior of the policy

Hence, the difference between imperative, declarative, and other types of policies lies in how the elements of this three-tuple are used according to that particular programming paradigm. This is how [SUPA] was designed: a Policy is a container that aggregates a set of statements.

6.4. Policy Subjects and Policy Targets

Policy subject is the actor that performs the action specified in the policy. It can be the intent management system which executes the policy. Policy target is a set of managed objects which may be affected in the policy enforcement.

6.5. Policy Scope

Policies used to manage the behavior of objects that they are applied to (e.g., the target of the policy).

It is useful to differentiate between the following categories of targets:
o Policies defined for the Customer or End-User

o Policies defined for the management system to act on objects in the domain that the management system controls

o Policies defined for the management system to act on objects in one or more domains that the management system does not directly control

The different origins and views of these three categories of actors lead to the following important differences:

o Network Knowledge. This area is explored using three exemplary actors that have different knowledge of the network.

Customers and end-users do not necessarily know the functional and operational details of the network that they are using. Furthermore, most of the actors in this category lack skills to understand such details; in fact, such knowledge is typically not relevant to their job. In addition, the network may not expose these details to its users. This class of actor focuses on the applications that they run, and uses services offered by the network. Hence, they want to specify policies that provide consistent behavior according to their business needs. They do not have to worry about how the policies are deployed onto the underlying network, and especially, whether the policies need to be translated to different forms to enable network elements to understand them.

Application developers work in a set of abstractions defined by their application and programming environment(s). For example, many application developers think in terms of objects (for example, a VPN). While this makes sense to the application developer, most network devices do not have a VPN object per se; rather, the VPN is formed through a set of configuration statements for that device in concert with configuration statements for the other devices that together make up the VPN. Hence, the view of application developers matches the services provided by the network, but may not directly correspond to other views of other actors.

Management personnel, such as network Administrators, have complete knowledge of the underlying network. However, they may not understand the details of the applications and services of Customers and End-Users.
o Automation. In theory, intents from both end-user and management system can be automated. In practice, most intents from end-user are created manually according to business request. End-users do not create or alter intents unless there is change in business. Intents from management systems can be created or altered to reflect with network policy change. For example, end-users create intents to set up paths between hosts, while the management system creates an intent to set a global link utilization limit.

7. IANA Considerations

This document includes no request to IANA.

8. Security Considerations

This document does not have any Security Considerations.

9. IANA Considerations

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10. References

10.1. Normative References


10.2. Informative References

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Abstract

This document presents an overview of the concepts of Network Intent and provides definitions for some of the nomenclature. Some potential use cases are presented.

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1. Introduction

Recently, there have been deployments of networks of Service Provider, enterprise and data centres in a very large scale. From a network management perspective, the manageability of networks of such scale poses new challenges. The increasing complexity of network configuration is an additional challenge for the network administrators. To an extent, for device-level configurations, there has been standardization efforts underway in technologies such as YANG [RFC6020], and NETCONF [RFC6241]. However, the challenge still remains at the network level configuration, orchestration and management. The complexity of the network can lead to potential mis-configurations and furthermore, it may be difficult to troubleshoot the network failure conditions.

From a management perspective, it is of paramount importance for the network administrator to reduce the complexity of the network management. There are several measures and approaches that have been under consideration towards that objective. One aspect that has gained attention is Network Programmability APIs in the management plane. Programmability allows the capabilities of network functionality to be modified or extended. Programmability promises to enable the development of a whole new wave of applications that provide additional management intelligence. Programmability enables the development of applications whose purpose is to make the networks easier to manage, and those applications can be embedded and tightly coupled with the network. The application developers can use the Network Programmability APIs that can allow them to add new features that can facilitate ease of network management, efficiency and the
effectiveness with which the network can be provisioned, administrated and managed. Programmability, as provided through SDN, provides exciting new opportunities to increase manageability by facilitating the development of corresponding applications. Software defined networking (SDN) is an umbrella term for a programmatic approach to managing network devices, using software controls to replace manual configuration. Initial motivations for SDN were to overcome the lack of network programmability, and manageability in networks.

SDN technologies allow network-wide visibility and the possibility of feedback actions across the network. The desire to implement higher layers of management abstraction such as policy-based management, or the desire to extend an application’s capabilities with application-specific pre-processing that can be delegated to the network.

Leveraging the Network Programmability APIs opens the possibility to introduce an abstraction for the network, which can be used to synthesise the overall system behaviour. In the networking parlance, there have been several concepts that have been considered to simplify the network management - Network Policy, Autonomic Networking, Service Models, and Network Configuration. We introduce the concept of Intent Based Networking, by which the network administrator can articulate a desired outcome to the network. The Network Intent is translated to appropriate network policies and/or network configurations. With this approach to Network Intent, the focus is more on "what" the network should do and less on "how" i.e., the intermediate steps that should be executed. This level of abstraction can be referred to as "Network Intent". The implicit assumption is that for "Network Intent" there might be some prerequisite steps that may need to be performed, such as the network elements are discovered and controlled, and device capabilities and features are identified.

While there has been investigations of Network Intent, there are some still ambiguities in terms of the terminology used. This initial proposal is an attempt to clarify some of the terms and provides a brief outline of the goals or the vision intended. Some use cases are presented to illustrate the concepts introduced in this document.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].
3. Hierarchy of Manageability

There is a certain non-physical, logical hierarchy in a network management environment, as described in the figure below. The user at the top of the hierarchy can be represented by a "real" user or a system that performs actions on behalf of a user, such as a management station.

The "user" establishes an "intent" to be taken on the network as a whole and pushes that intent to the second layer of the management hierarchy, which consists of the intent engine.

The next layer of the hierarchy consumes the "intent" and translates the intent to desired actions based on the meaning of the intent.

The bottom layer of the hierarchy consists of the devices on the network that consume the configurations and actions issued to them by the intent engine. These devices sit directly on the network and are responsible for traffic flowing through the network.

```
+---------+
|  user   |
+---------+
      | Intent API |
+----------+----------+----------+----------+
|  SDN     |  Controller |  Intent Engine |  Device  |
        +----------+----------+----------+----------+

Figure 1
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4. Network Configuration

Network configurations are the most basic atomic operations that can be performed on a network device. A particular feature of the network software can be enabled by one or many lines of network
configurations. Often the network devices are configured by experts with _domain expertise_ and based on the functionality the network device has to perform. Often, network configuration is performed on a device by device basis and this is a manual process. Automation of this process is very important step, which can save time and reduce the possible number of mis-configurations.

5. Network Policy

Policy based network management has been widely discussed in the literature [JNSM]. Several proposals for the semantics and structure for expressing network policy have been considered. There are some particular implementations and deployments of network policies such as Performance Forwarding, QoS profiles etc.

A network policy can be viewed as a set of rules a network administer can use to manage the network resources; for example to provide differential treatment for traffic. Policies can be at a network level and can provide a way of consistently managing multiple network devices. The administrator can define policies and specify how the network devices should deal with different types of traffic. Policies can be defined to be conditional, in the sense, if there is a condition A is observed, then a set a network policy can be implemented on some network devices. Policies can be a group of network configurations which perform a specific function that can be applied to network devices. In the SDN paradigm, network policies can be pushed to the network devices using NETCONF [RFC6020] and RESTCONF [RFC8040].

6. Network Intent

Network Intent can be considered as a declarative paradigm by which the network administrator articulates a desired outcome or the state of the network. In abstraction, the network enables a set of services that can be consumed. In particular, Network Intent is a desirable functionality that can be enabled from an SDN Controller. There are potential benefits of ease-of-use and operational simplicity and the capability of programming the entire network.

Network Intent need not be prescriptive or expressed explicitly in terms of specific actions. The following are the intended design considerations of network intent.

- First, there may be several alternative approaches to realise a specific Network Intent.
Second, it is conceivable that it may not be possible to realise some of the Network Intents due to non-availability of network resources or the network may not have functionality.

Third, some new Network Intent can be in conflict with the current state of the network or can disrupt the Network Intents expressed previously. It is assumed such a feedback regarding the conflicts is provided back to the administrator the originator of the Network Intent. Based on the feedback, it should be possible for the network administrator to refine the new Network Intent.

This proposal or definition of Network Intent can be viewed as analogous to the promise theory framework proposed [Promise]. In order to realise the Network Intent, it may be useful consider a logical functional block – the Intent Engine – that can resolve the network intent and render the Network Intent appropriately on to the network.

The simplistic method to realise network intent is to consider linear one-to-one mapping of Network Intents to actual network policies or network configurations. In a more general framework of Network Intent, it should be possible to consider a more general approach leveraging artificial intelligence based techniques so that the Network Intent can be accurately realised and appropriately rendered on the network. Translating the intent requests to rendering actions would require the modelling of network devices and the functionalities and configurations.

In order to realise a Network Intent eventually that should consist of network configuration blocks that can be implemented in one or more network devices.

There is a general confusion between policy based network management and intent based network management. An analogy can be drawn between intent based network management and the automotive industry. Though cliched, this analogy provides the closest match. Many cars, if not all, have cruise control as a function today. Cruise control is a very simplistic functionality that keeps the car going at a specific speed. It monitors the speed and adjusts it up or down. This can be considered as a policy, to keep the car driving at certain speed, until the operator disengages the policy manually.

An car that can handle intent would, on the other hand, accept a request such as "take me from San Francisco to Los Angeles within 6 hours," plot the appropriate path based on historical data on which roads are the best ones to take to achieve the constraint of reaching within 6 hours and plots the direction to go in. Then it would constantly monitor the traffic on the path and provide feedback to
the operator about whether the path chosen will still achieve the constraint. If the constraint cannot be achieved, then it either replots the path or lets the operator know that the constraint cannot be achieved and requests a new constraint. The operator is removed from making the decision about which exact path to take and is instead just providing the constraints that need to be achieved.

7. Use Cases

This section lists certain use cases that showcase the value of intent based network management. There are a variety of use cases where intent based network management is of value but the highest value is present in scenarios where a network needs to be reprogrammed in a significant manner in the shortest of time frames. Such a network reconfiguration should not result in misconfiguration that could result in the loss of communication capabilities for the users of the network.

We provide two scenarios where such a reconfiguration of the network is required. There are obviously many more day-to-day scenarios where the intent of change or monitoring of a network can be of a much lower scale.

7.1. A simple example

The network administrator articulates the Network Intent, "Route traffic from Node A to Node B with minimum bandwidth of K mbps". The Intent Engine then resolves the intent. This step involves understanding the intent expressed and the second step to resolving that intent would require performing routing calculations between Node A and Node B. This is a key step involved in this proposal.

Once the intent has been resolved, routing calculations are well-known and there are standard techniques taking into account the network topology between Node A and Node B; the current utilisations with minimum guaranteed bandwidth of K Mbps between Node A and Node B. Once the path is determined, that routing and next hop configurations are communicated to the respective network nodes.

7.2. Disaster Management

Planning for disaster management and sudden reconfiguration of infrastructure is common in the "physical" world - ie roads, water supply, electricity, etc. Similar reconfigurations of communication networks also is important during a disaster. During a disaster management / recovery, it is important to ensure that emergency communication traffic (such as 911 in the USA, 999 in UK and similar in other countries) gets more bandwidth and resources than non-
emergency communication. It is also important to allow people to communicate with their family members inside and outside the disaster area, to help in recovery efforts. For this reason, voice communication, including VoIP, should be prioritized over streaming video services.

Such a disaster management is geographically bounded, therefore the network changes need to also be appropriately geographically bounded. This is very often hard to apply manually in a very large network at the moment that the change is needed. Intent based networks can provide an abstraction that use the underlying knowledge of the network and policies to achieve an action to provide this ability in a finer grained manner.

As the disaster scenario subsides the applied intent should automatically subside as well. This requires not only action to be taken based on policies, but also requires constant monitoring of the operational state network. Such monitoring presents significant amounts of data and it is quite hard to build rules and conditions to operate on such data while minimizing mistakes. Machine learning based monitoring can provide a mechanism to make applying an intent easier, especially in very large networks. Such machine learning based mechanisms can be integrated with physical world monitoring to identify when a disaster hits a certain geography and to automatically trigger a pre-set intent for that scenario. With such machine learning mechanisms and multiple pre-set intents, it would be possible for a management system to automatically trigger a specific intent when it detects a particular scenario. Similar combination of operational monitoring and intent based networking mechanism can be used to withdraw an intent when the disaster like scenario recedes.

8. Issues with Intent based networking

Intent based network management is about creating an abstraction to handle the management of a network. Naturally issues related to any abstraction mechanism applies here as well. Specifically, an abstraction like this removes the direct interaction of a user with the network for operations management. While the original creators of this intent, and the associated policies, would have understood the reasoning behind this intent, and more importantly the fine distinction between when to apply and when NOT to apply such an intent, later users of the system may not have that clear distinction and may apply this intent needlessly. This problem exists in any abstraction mechanism.
9. Security Considerations

This draft currently does not impose any security considerations.

10. IANA Considerations

This memo has no actions for IANA.

11. References

11.1. Normative References


11.2. Informative References


Authors' Addresses