A Discussion on Policy-based Management using Context Mobility in Ad-Hoc Networking

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***Abstract*— Much of the current research in the field of Information and Communication Technology has focused on pervasive and ubiquitous computing. It is an environment where converging technologies and devices are distributed, highly mobile and often intelligent. This discussion paper looks at using Policy Based Network Management (PBNM) with Context to simplify configuration management for mobile or ad hoc networks.**

Two areas form the background to this work: Policy Based Network Management and Context. Policy based network solutions provide flexibility and granularity in an environment that is ever growing and increasingly complex. Context adds intelligence by adding information, thus allowing policies to be adaptive to their environment and the decisions (potentially) to be more relevant. With configuration management, Discovery Services will also play a role.

***Index Terms*—Policy Based Management, Context, Mobility**

I. Introduction

CURRENT research in the field of Information and Communication Technology (ICT) has focused on pervasive computing environments, where converging technologies and devices are distributed, highly mobile, and often times intelligent. This brings new challenges and additional costs in terms of management and administration. With the given complexity, it is no longer viable to consider manual management of devices, users and systems. Hard-coded algorithms will be obsolete and more flexible solutions will gain importance [1]. Future systems need to be adaptive and many will be based on policies set by organizations. Context will be used to add intelligence and increase relevancy in decisions.

In the past PBM systems were relegated to areas of research or to larger organizations. The cost of set up and implementation meant it was prohibitive for many. The impetus for implementing PBM systems based on Context in the future may be the lure of “anytime, anywhere” computing. An essential feature of future intelligent network applications is adaptive services based on context [2].

In this paper we *discuss* where Policy Based Management using Context can simplify configuration management in a mobile and Ad-Hoc networked environment. Although Policy and Context can be applied to other management areas as well, these are not discussed in this paper.

II. Policy-based Management

Early PBNM information models lacked business and network-based entities. There was no way to define how the business rules could use policies, how network services would be controlled, or how a policy rule would be evaluated. These systems were not closed loop – they did not tie the business requirements of the system to the individual actions with a feedback mechanism for evaluation. This, however, has changed and the recent focus of PBNM systems has been on the integration of business rules and processes.

A. NGOSS Policy-based Management

Next Generation Operational System and Software (NGOSS) defines an architecture for automating business processes. Policies choose a set of processes to perform a function. Feedback from executing processes can change policies that are in force (or applicable) for any particular time. At a high level NGOSS defines the definition of a policy model that includes business, system and implementation viewpoints.

Business rules and processes, device configuration and service activation are all tightly bound together [11]. A robust, extensible model needs to represent the managed environment as a set of entities. If policies are also entities, then they can be represented using the same tools and, therefore, be applied to users, applications, device interfaces, services, or other managed objects. The information model provides the formalisms through which a robust system can be built.

Different from most, Directory Enabled Network – next generation (DEN-ng) – an object oriented information model developed by the Telemanagement Forum – uses a finite state machine to represent the state of a managed entity. Typically these models are current state (i.e., they define a managed entity to represent the state of an object). However, this does not enable the life cycle of the object to be represented. DEN-ng instantiates multiple current state models to represent different states of a managed object. This allows the behavior of an object to be related to the value of one or more attributes representing the current state. The changing of this value represents an event that can be used to trigger the evaluation of a policy rule. Thus, policy has been redefined as a means to control when a managed object transitions to a new state [11].

B. IP Configuration Management

RFC3139 identifies a set of configuration requirements for IP based networks. It defines a configuration management process that adds a layer of abstraction to provide for an efficient, integrated management solution.

First a network model and its expected behavior is created by the administrator. This is formalized and recorded in the form of high-level policies. These policies are combined with topological and status/performance information to generate network-wide configuration data. These form the middle-level policies that are simpler to manage and represent behaviors shared by multiple network devices. Automated configuration data translators generate device local configurations. The translators may reside outside of the devices or be co-located within each device.

This model allows network operators the ability to specify the behavior of the network in a simplified manner reducing the amount of device specific knowledge needed. High-level policy changes (to the topology or its expected behavior) need to be propagated to all network devices affected by the change. This higher level of configuration management has come to be known as policy based management. In some cases per instance device local configuration is needed in network devices and any integrated solution must provide for this.

C. PBM in Ad-Hoc Mobile Networks

[3] presents state of the art work in the area of PBM of Mobile Ad Hoc Networks. It is based on a military field environment where the ability of the network to react and function properly is crucial to the success or failure of military operations. The management system allows a mobile and highly dynamic ad hoc network to be automatically configured and reconfigured in a secure environment. Specific capabilities within the technology include:

– Dynamic changing of a node's role to act as a server, based on capabilities such as power, signal strength, etc.
– Switching between proactive and reactive routing protocols to optimize performance depending on the known density of nodes in the network.
– Adjusting auto-configuration address pool sizes
– Setting network-wide values for auto-configuration

The network requirements are expressed at a high level and are automatically realized by intelligent agents. A variety of protocols are integrated to provide flexibility and optimization of network resources.

The US Army MOSAIC Ad hoc Mobility Protocol Suite (AMPS) provides mechanisms for dynamically merging and splitting networks. Dynamic Configuration Distribution Protocol (DCDP), a robust, scalable, low-overhead, lightweight protocol, is used to distribute configuration information. Dynamic and Rapid Configuration Protocol (DRCP) automatically detects the need to reconfigure (e.g., due to node mobility) through periodic advertisements and operates without central coordination.

User defined aggregation and data filtering at the source reduces management processing and network transmission overhead. Survivability is achieved by enabling any component to take over the management role of another in case of failure and an automated feedback loop allows triggers to correct network problems.

III. Context

Current work on context is surveyed in [4]. As humans we increase our understanding (or "conversational bandwidth") by using implicit situational information, or context. A key question is: how can we make applications aware and responsive to the context of human-computer interaction? Mobile computing, and the wide range of possible user situations this brings, provides opportunities to use services that adapt appropriately to the user's environment. Primary context types include: location, identity, activity, and time.

[6] tackles context from the perspective of the network. They define context as: "any information, obtained either explicitly or implicitly, that can be used to characterize one certain aspect of an entity involved in a specific application or network service." They define a context-aware service to be: "one that uses such context for service provision."

[7] lists potential benefits of using context. They include: ability to access services spontaneously, provide initial configuration, ability to discover services semantically, rapidly adapt to service changes, and compose services.

A. Context Categorization

In [5], Context is divided into five categories for the purposes of extracting information: time, location, user, environment, and device. It documents several automatic and semi-automatic methods currently available for extracting context information:

– Time - can be extracted from a clock on the device or from an external source such as the mobile network.
– Location - can be extracted in a number of ways including through GPS or estimated with the help of a network operator or through the location of access.
– User - mostly semi-automatic whereby a user specifies context information once; and, triggers automatically keep track of which contact information is active.
– Environment - parameters such as sound and light can be analyzed using common devices such as microphones, digital cameras, or specialized sensors.
– Device - device information, such as knowing how it is being used, how fast it is traveling, or what applications are being used.

B. From Mobility to Connectivity Management using Context

Pervasive networking and multi-connectivity requires new models, methods and new paradigms. [2] suggests the focus must change from mobility management to connectivity management. In this case, the aim is no longer on managing the mobility of the device but, rather, on ensuring connectivity collaboration.

Being multi-mode is a basic device requirement if a terminal is to have multiple network connections. Many devices today have this feature. Future applications will use several of these applications simultaneously. Devices will need to be able to auto-configure and automatically adapt to their environment.

An argument for using much more connectivity context is presented in [2]. Context can be collected from the underlying infrastructure and from service providers for use by middleware and applications. It can be used, for example, for device auto configuration.

IV. Related Work

For related work, we focus on two areas and provide examples for both of them. The first presents arguments for a policy based context aware service for next generation networks (NGN) based on using Service Level Agreements. The second is a policy-based solution for 4G mobile devices incorporating rich context yet maintaining a light weight solution for smaller handheld devices. Both of these use policy based management and context for network connectivity management.

A. Policy Based Context Aware Services for NGN

[6] provides a rational for using a policy based context aware service system for NGN. They use a super-mother scenario to demonstrate the applicability of policy based context-aware services, in which every entity is described by four basic context features: identity, location, activity, and time. An entity can be "a physical object such as a person, a place, a router, a 3G network gateway, a physical link, or a virtual object such as IPsec tunnel, or an SNMP agent."

The system models a subscription service that allows dynamic switching of the network connections based on availability of resources and the user's requirement. To facilitate the provision of this service requires an appropriate infrastructure to gather, manage, and disseminate contextual information. The PBM part of the system is organized in terms of the IETF Policy Framework Group. The four components include: policy management tool, policy repository, Policy Decision Point (PDP), and policy Enforcement Point (PEP).

B. A Policy-Based Solution for Future 4G devices

PROTON, A policy-based solution for 4G mobile devices, is presented in [1]. It describes a policy-based solution that uses context to manage network connectivity in a 4G environment whereby users access many networks using a multimode device.

The PROTON solution is based on networking context and a policy model. Networking context is divided into fragments and includes items such as presence, status, connection, signal strength, latency, etc. It is grouped into a hierarchy based on the dynamic and static components and complexity in the rules applied. Static components include items such as network profile, application profile, and user profile.

The main components of PROTON are Context Management, Policy Management, and the Enforcement group. The Policy model follows the IETF Policy Core Information Model (PCIM) and it provides the following benefits: a) policies can be tagged with different roles; b) policies can be assigned; and c) the model can be translated to XML[1].

PROTON is an attempt to address the flexibility and adaptive-ness that will be demanded in future environments. Like much of the current research in the area, its primary focus is on network mobility management and, in particular, vertical handover (when a mobile device changes its point of attachment to a different access network). A PBM approach to mobility management is presented next.

C. Intelligent Access and Mobility Management Using Policy

PBM is used for mobility management in heterogeneous systems in [8]. Their attempt is different than previously presented as they look at initial call placement to optimize overall network capacity and Quality of Service (QoS). The system allows the user, in a heterogeneous wireless networks, to seamlessly roam between different access technologies and maintain network connectivity and satisfactory QoS.

Their Policy System Architecture includes a Network Policy Engine and a Mobile Policy Engine. The network policy engine is responsible for selecting an access network and for making call admission control decisions. The mobile terminal policy engine is responsible for mobility management procedures – deciding the correct time for a vertical handover and to which network it should change its point of attachment.

Policies are used to decide which network can best support the requested service (at the call initiation stage) and in deciding the best time to implement a vertical handover to another access network. A network health monitor is used to monitor the stability and performance of the network. It is based on a formula that includes looking at the frame drop rate, the block error rate, and voice blocking; and, it is part of the networks admission control policy. The Policy Enforcement Point (PEP) executes the decisions by the PDP (i.e., it either allows admission or not).

V. Simple User Scenario

In an environment where devices are mobile and frequent changes are considered the norm, systems must react automatically and dynamically to the world around them. We use printers to provide an example of how configuration management might work using Context and PBNM. Based on the printer's location, the PBNM system can be used to direct a user's print job to the appropriate printer. A selection policy(s) can control the printer selection procedure. Policies describe the conditions and, when the conditions are met, policies also describe the action to take. Print jobs are directed to the appropriate printer based on enforcement of the policy rule. A printer can be selected that best meets the user's requirements based on user location and device location and availability. For example:

- If a user goes to another floor (or building), he can use a printer closer to him, instead of his default printer, if the system knows his location and that of the printer.
- If his default printer is out of service, he can use another

nearby printer automatically if the system knows the printer status and location of both the user device and printer.

– Where a new printer is installed on the floor, the user can automatically use the printer without manual changes.

Use of a different printer in these examples can be automatic and dynamic using policies and context for configuration management. Although configuration management of printers is used to illustrate the points that follow, the concepts discussed here can apply to other devices as well. In the following, we identify the four basic scenarios.

A. *Static device added*

Although devices can be relatively static over a short period of time, they will move regularly over longer periods. This typically necessitates reconfiguration of devices. Using the printer's location information with PBNM can simplify this process. A context information base can be a source of information to pull details of the device and its location. The Ethernet port location, information from SmartLabels and sensors, or manual entry of information into a printer terminal can be used as input to this base.

B. *Static device moved*

Devices may move, temporarily or permanently, within a floor and this may or may not necessitate a reconfiguration of their printer profile depending on location. In either case, PBNM with context can simplify any needed changes. For example, a or printer is permanently / temporarily relocated on the floor; a printer is permanently / temporarily moved from floor 1 to floor 2

Users also move between floors either temporarily or permanently. The resulting move may necessitate a reconfiguration of their printer profiles. This can be simplified with PBNM using context information based on the user's terminal location.

C. *Static device removed*

When a printer is removed this must be updated and reflected in the network. Maintenance of configuration information is often time consuming and one that sees little pay back to a company. Automating this can reduce costs and provide for a more efficient network.

D. *User (or mobile device) changes location*

Nomadic and mobile users roam and move about. They often need to print wherever they are located and this is not easily done with today's technology. The printer examples above (where devices join and leave the network) can be extended to support the nomadic mobile user. PBNM used in managed Smart Spaces can provide access control and QoS to these users in a managed network.

Whereas with printers, devices join and leave the network through physical connections or sensors; nomadic users join or leave by using one or more of a number of access technologies (mobile IP or cellular IP).

Client devices also need a default device driver if they are to access the printers and they need the printer's address and the name of a print queue. Both of these can be supplied as part of the PBNM system.

VI. PBM Configuration Requirements

A PBNM system operates on a system of rules. Policies are implemented on rules (defined by a condition/action pair(s)) and these are enforced in devices throughout the network. The devices that enforce the rules may be routers, gateways, or even end user terminals. A defined condition can be met when triggered by an event. For configuration management the events can be: (a) device joins the network, or (b) device leaves the network. Policy rules define how the network handles the event. The evaluation of the rule determines the policy decision.

In our scenario we are interested in the printer; however, any device can be managed in the same way. From a management perspective, the network should accurately reflect its current state. Although some delay is tolerable, management can only be effective if it is done when actions are taken based upon correct information.

There are several management functions required for devices that participate in the network. These include: use, operation, control, maintenance, and update. When a printer joins the network, its configuration must be updated to allow the administrator to perform management functions on it and also to allow users to access and use it.

Likewise, when a printer leaves the network, this needs to be reflected in the network configuration. The specific printer requirements for our system can be listed as follows:

– If you remove a printer, it should automatically remove itself from the network
– If you add a printer, then it should automatically add itself to the network and allow workstations to print on it.
– Location tells the network where a printer is and determines configuration requirements
– Location tells the network where a client device is and determines configuration requirements

VII. PBM Scenarios with Context

Our PBM system is described in [9] and [10]. It follows the classical approach by distinguishing between administration tools (GUIs), Policy Decision Points (PDP), Policy Enforcement Points (PEP) and policy repository. COPS is used for communication between the PDP and the PEP.

The system can be deployed in a hierarchical way. A Master PBM (M-PBM) can select between one or more secondary PBMs (S-PBM) to employ based on location or it can use context, such as device type or user profile, to decide what policies to send to the S-PBM. Admission control can be used to add and remove devices to the system (see [8] for an example). In the following we show the general work flow of the PBM system from the previous scenarios

A. Printer Initial Configuration/Reconfiguration

When a printer initially joins the network (it is new, or is moved from one location to another), it must be configured. The M-PBM System is the first point of contact. Its address could be provided as a Domain Name in the DHCP. The M-PBM would point to the S-PBM system based on the location of the workstation device requesting the print. The S-PBM identifies a managed space. Context information, specifically the printer's location, is used by the S-PBM to supply the configuration information. In this scenario there is no DNS Server. When a workstation requests a job to be printed it is directed by the S-PBM to the appropriate printer.

B. Initial Print Request

To look at a print request we assume the workstation has been assigned to a S-PBM based on its location. When it needs to print it will request a printer from the S-PBM. The secondary returns the address for a suggested printer based on the type of document it is printing, the location of the workstation, the location and type of printers nearby, and the location of the user requesting the print.

C. Printer Disconnected

There are two scenarios for when the printer is disconnected: one where the PBM is notified and one where the printer is simply unplugged and, therefore, the PBM is not notified. Both situations must be considered.

D. Printer Disconnected and PBM Notified

In the situation where the printer is disconnected and the PBM system is notified, there is an orderly shutdown. The printer notifies the S-PBM that it is leaving. This may be set up through the OFF button with the use of policies. It is a condition that can trigger an action and therefore it can be modeled as a policy. The action can be triggered to have the S-PBM release its configuration; this will trigger the M-PBM to release it too.

E. Printer Un-Plugged, PBM Not Notified

In some cases a printer may be simply un-plugged. The S-PBM is not notified and will still retain incorrect configuration information. The PBM will need to occasionally monitor the printer's connection. The S-PBM can periodically issue a "hello" to the printer as COPS uses TCP. If the printer responds, the S-PBM knows it is still attached. If there is no response, policies can ensure the S-PBM will release the configuration and notify the M-PBM to do the same.

The situation where the PBM is not notified can cause a number of problems as it has incorrect configuration information. These problems, however, can be minimized.

In the case where an S-PBM has not yet issued a hello to a disconnected printer, there is a possibility it may still direct a user to the printer for a particular print job. In such a case the user will receive a print error if it tries to print. In this case, the S-PBM can be set up to send an immediate "hello" to the printer to release the configuration sooner and then direct the user's print job to another printer in its location.

In a separate but related situation, a re-connected (but different) printer may be issued an IP address by the DHCP that has been already released by the DHCP but not the PBM. In this situation, the PBM can immediately release the configuration for the "old" IP address before it allows the same "new" IP address into the PBM system with its configuration information.

F. Device Configuration/Disconnection

The above scenario can be extended further to include workstations - both stationary and mobile. The DHCP and PBM operate at the device level. It only knows the type of device it is dealing with based on context information as provided by the device.

VIII. Adding Context to a PBM System

The proposed class inheritance hierarchy in [6] is used as part of a context information model in a network centric context aware system (i.e., it has the ability to take into account the main underlying network implementation technology). In the system, context is used to dynamically manage connections to different networks. The addition of Context types follows the IETF standards for PBM systems.

Context is stored in the LDAP directory. Location is the type of context information chosen for our example and it is used to assign the printer's device configuration and the user's print device. In the previous scenarios, the M-PBM system controls one or more secondary PBM systems. When a printer initially joins the network the M-PBM is the first point of contact. The Master points to the S-PBM based on the location of the printer and this is used by the S-PBM to supply the configuration information.

A set of profiles for devices, users, and locations allow for context-aware configuration. A service (printer) can be assigned a deviceProfile (e.g. b/w Laser, inkjet) and a location. Each location determines the configuration assignment. Each configuration may contain one or more device profiles.

To use context location information in the configuration scenario, a policy needs to be defined that assigns a device configuration based on location. For example:

```
if (( sourceIPAddress = valid) AND
(userProfile = employee) AND (location = x)) then
set SecondaryPBNM:= x
```

A new printer service installed on the second floor will be assigned the S-PBM for the second floor. The S-PBM for floor 2 uses the configuration for floor 2. The configuration is made up of several profiles depending on the type and location of the printer on the floor. The profiles determine the specific configuration requirements for the service. Each floor can have several profiles, and each profile can consist of one or more physical printers. Users on the second floor who need to print use the configuration for the second floor.

Likewise, when a new terminal is installed, it is assigned the S-PBM for the floor,which uses the configuration for that floor which is made up of several terminal profiles depending on the type and location of the terminal. When the terminal needs to print, the request goes to the S-PBM that finds and assigns a default printer based on location and user requirements.

This is easily extended to a mobile user. As the location of the printer and workstation determine the configuration to use, the location of the mobile user does as well. As in the previous example, the choice of a printer for a particular job is based on the location of both the user (whether mobile or not) and the printer. Context location information is used in each case but it may be gathered differently depending on the user device.

Location information for the mobile user is available through, for example, the location of Access Points or obtained by triangulation or through sensors and RFID. No additional functionality is needed in the system for configuration management even with mobile users. These users join and leave the much like a printer or terminal device does. Their frequency of movement may be different but the system, as presented here, will operate the same.

IX. Summary and The Big Picture

In this paper, we have focused very much on a single and simple scenario: printing. We describe our communication environment as an 'ad-hoc network', which in turn might be arguable. However, ad hoc (or impromptu) reflects an environment which is devised for the purpose at hand. Ours is printing. The printing service we discussed as one example focuses on two aspects: configuration management (connect to a printer and print) and seamless or continuous service usage (print 24/7, not just when a printer decides to be active). One can use this scenario and extend it to any kind of spontaneous mobile network, where handover and sessions mobility become more problematic then our two aspects. Although that might be more interesting, the basic problem stays alive: how to we use contextual information within a policy-based management system. Traditional PBM systems and languages (i.e. Chaos, Rai, Ponder 1/2) don't have the notion of context.

But there is help, if one turns to for instance Autonomic Networking. Here, we developed an information model (SID) which intrinsically associates context with managed entities and policies. These associations are expressed by means of: using context, selecting policies based on context, selected policy (and associated action) changes context, context depends on managed entity role etc. The SID, in combination with a closed control loop, enables context-aware decision making using policies in fixed and mobile networks, for printing and handover alike. For more information in actual information modeling, control loop design, system architecture and complex scenarios, please see [12]. For technical advances in managing pervasive computing environment please refer to [13] and [14]. Both of these workshops have been held focusing on the integration of traditional (network management (such as Policy-based management) and pervasive (or ubiquitous) computing environments (which rely/focus on contextual information).

This paper focused at the hart of the problem, using a simple scenario because we didn't want to dilute our discussion and distract the reader from what is the key problem: static policies do not solve an operator's needs.

X. Conclusion

This paper has *discussed* using Policy Based Management with Context to simplify configuration management for ad-hoc networks. Policy based solutions provide flexibility and granularity in an ever growing and increasingly complex network. Context adds knowledge that can be used to make policies adaptive to their environment and, therefore, the policy decisions more relevant. The benefits of these solutions are many and this has led to continued interest in the field and opened opportunities for further research. This work looks at state of the art technology in Policy Based Network Management and Context. Much of the interest in the field has been focused on connectivity or mobility management. We focus here on configuration management. In the discussed example, location information is used for context although much more is available. Future work may consider implementing other context types such as time, device activity, user profiles or metadata.

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