Policy-Based Multi-Level Routing: Dealing with Uncertainty in the Provisioning Process of the First Mile Part of DSL-Based TelCo Products

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Abstract: The copper-based First Mile is the blind spot of a TelCo. While the Second Mile comprises active network components that can report status and configuration, the First Mile largely consists of passive components. Hence, any information about the First Mile can only be obtained from the TelCo's database. Given the high rate of change in First Mile data due to provisioning for new customers as well as product-changes, network extensions and a number of other causes, this data cannot be guaranteed to reflect the First Mile's reality. This situation is aggravated by the fact, that some parts of the First Mile are decades old and the data granularity required by modern DSL products exceeds that of the data gathered in the pre-DSL era.

This paper proposes an approach to tackle uncertainty in First Mile data by introducing a policy-based approach avoiding re-routing or re-checking connections on a pin-by-pin level. Instead, a connection is built by assembling existing sub-connections. A connection's properties are computed by its sub-connections properties which in turn are stored as facts in a database.

1 Introduction

The First Mile is the oldest part of the infrastructure of a modern TelCo. It is a large network of copper cables providing a connection to each telephone socket throughout the country. Within this network copper cables are connected by different types of nodes. For connecting customers, new wirings have been added over the years, other wirings needed repair. As changing the First Mile network is an every day task for a technician there are a lot of small changes. Additionally the copper network was installed long before database systems existed so a network model had to be created and stored in a database belatedly. Future business scenarios will call for renting and selling of lines to/from other TelCos. All these issues cause highly dynamic changes within the first mile.

The First Mile infrastructure mainly has no active components so it is not possible to extract the data of locations and wirings automatically out of its components. The Second Mile network is completely different. Here active components are deployed which are able to send reports resulting in a much better knowledge of the status of the Second Mile infrastructure [HK01].

Apart from that, TelCos have changed from traditional voice service providers to IP based service providers replacing the old telephone service by Voice Over IP [VSMH02]. Besides new products are coming up requiring high bandwidths like IP-TV [NGG04]. It is only possible to provide high bandwidth rates if the copper cable line meets a number of physical constraints. Some of these contraints even include bandwidth on neighboring lines. Additionally the telecommunication market has been opened, so a lot of alternative TelCos came up. It became possible to hire network resources out of these networks. Currently a lot of detailed information about the wiring of these hired lines is needed[MSS08]. However, by using a different approach the need of detailed information can be avoided. It is enough to know that there exists a connected and operational line that supports the desired bandwidth.

2 A poliy based approach for finding connection paths in TelCo Networks

A policy is implemented by a set of operative rules. Systems that realize policy management provide rules for different levels of abstraction. The most abstract rules are those that represent top level decisions. By adding, removing or modifying policies that are part of different levels of abstraction, the strategy or behaviour of a system can be changed. Ideally this would mean that a manager could steer a system's behaviour on a very coarse, strategic level and every policy set by the manager would be propagated in a way that changes all relevant parts of the system to support the manager's decision.

2.1 Related Work

The usage of policies for managing networks has created the term Policy based Network Management (PBNM). When PBNM came up about 10 years ago, most of the proposed systems focussed on quality of service or security [FP02, Cha00]. Recently more general approaches were published [DAGBM09, RSLvdM06] proposing broader information models representing the operational environment next to the network. Policy based network management was also addressed by the TeleManagement Forum, who describe NGOSS Policy-based Management Systems in the context of their NGOSS architecture [For03].

Unfortunately, those approaches do not address the specific problems of the First Mile network. In a modern network, PBNM systems can interface with a so called network managing system (NMS). The network management system among other things automatically updates the inventory when physical changes in the network occur. As mentioned in the introduction, this is not the case in the passive copper network, resulting in a higher error rate. Another issue in the copper network is the static, customer specific routing. To be able to deal with those challenges we adapt the policy model and introduce a flexible description of the network.

2.2 Policy Based Routing in the First Mile Network

False or missing data in the First Mile Inventory is a big problem. However, one does not always need all the details about a customer's line. Often it is only necessary to determine weather a certain customer has a working connection or not. In case of new customers, it should still be possible to accomplish a routing that leads to a near optimal connection from the customer's telephone socket to a main distributor frame (MDF), even if small parts of a First Mile Network are unknown.

This can be achieved by describing the First Mile on different levels of abstraction, based on the available information. We define so called sub connections which represent a connection between single physical network elements up to a complete path from a customer's telephone socket to a MDF. Each such sub connection forms a logical abstract resource that can be associated with a policy. The approach is shown in figure 1. An exemplified path through a First Mile contains an unknown section. This section is hidden by policy D which describes the sub connection between node 2 and node 4. How the two nodes are connected in detail is not represented. All sub connections can be assembled by sub connection A which is the top level policy.

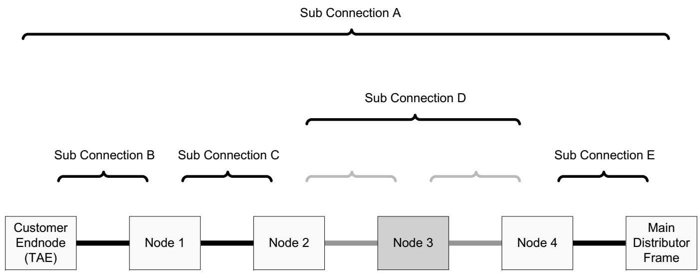

Fig. 1: Sub connections representing an exemplified path through the First Mile of a copper network. Unknown sections of the path are represented by a higher level sub connection.

According to the DEN-ng policy model [Str03], p. 56, a policy consists of a set of events, a conditon and an action. In our case the triggering event is an availability request for a certain DSL based product. The condition is a set of rules. Those rules are represented as Horn clauses, a subset of first order logic. Horn clauses provide sufficient power and allow for efficient resolution algorithms. The action is the construction of a provisioning plan that allows for the provisioning of the searched product.

Using Horn clauses, the description for the connection of node 2 and node 4 represented by sub connection D in figure 1, for example can be formulated just as any other sub connection:

```
subCon(node2, node4)
```

Those rules form a high level description of the network. The parameters node2 and node4 refer to a description of network elements as stored in the physical inventory. The corresponding action clause for that rule would load the representation of node2 and node4 from the physical inventory if a consistency check of the abstract model, represented by rules and the inventory is needed. Sub conncection A represents the end to end connection The parameters for the availability check of this connection must be set in the top level statement, which can be written as:

```
firstMile(telephoneSocket ,Y)
```

The resolution algorithm would then output paths to all MDFs that can be reached within the First Mile from the given telephone socket.

3 Proof of Concept

In order to further examine our idea a small part of a real world First Mile has been modelled by sub connectin. The corresponding rules have been implemented in the declarative language PROLOG. However, in order to explain our proof of concept, only a very simplified view on the network is used here. It contains only very few and high-level network elements. There are two possible paths leading from the telephone socket to either one of the two MDFs. One of the paths contains an unknown sub connection. The model is depicted in figure 2.

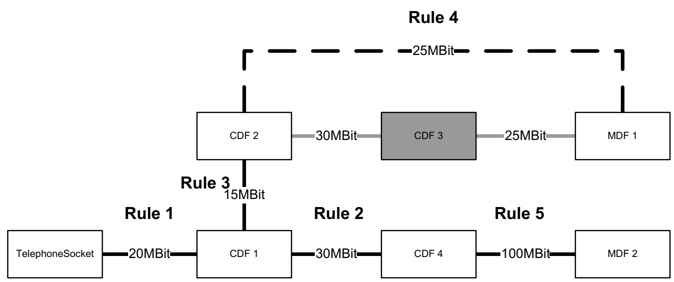

Fig. 2: A simplified model of a First Mile excerpt. There are two possible paths connecting the telephone socket to the Second Mile. The connections between known network elements are represented by sub connections.

We start creating rules representing the two MDFs (line 17+18). Then we create rules describing every known sub connection. The sub connections between cross distributor frame (CDF) 2 and CDF 4 and CDF 4 and MDF 1, respectively, are not known and are thus represented by a transitive rule connecting CDF 2 directly to MDF 1. The rules in line 3 and 4 represent the actual end to end connection. The first line specifies the top level rule, defining the end point of the path being a MDF. The complete code segment is shown in following listing.

```
firstMile(X,Y,D, P) :- con(X,Y,P), mainDistributorFrame(Y).

con(X,Y,P) :- subCon(X,Y,P).
con(X,Z,P) :- subCon(X,Y,P), con(Y,Z,P).

subCon(telephoneSocket,crossDistributorFrame1,P) :-
        ruleActive(rule1,P).
subCon(crossDistributorFrame1,crossDistributorFrame4,P) :-
        ruleActive(rule2,P).
subCon(crossDistributorFrame1,crossDistributorFrame2,P) :-
        ruleActive(rule3,P).
subCon(crossDistributorFrame2,mainDistributorFrame1,P) :-
        ruleActive(rule4,P).
subCon(crossDistributorFrame4,mainDistributorFrame2,P) :-
        ruleActive(rule5,P).

mainDistributorFrame(mainDistributorFrame1).
mainDistributorFrame(mainDistributorFrame2).

ruleActive(X, []).
ruleActive(X, [K | R]) :- ruleActive(X, R), X\==K.
```

If a path for a new customer should be found, one tries to prove that there exists a connection from a specified telephone socket to an arbitrary MDF. If the connection of an existing customer should be examined and the corresponding MDF is known, one tries to prove that a path from a specified telephone socket to a specified MDF exists. In the real world such paths must fulfil certain constraints like damping, length, and possibly some strategic parameters. In the present example, we ignore such constraints to keep the code shorter. Every sub connection can be activated or deactivated by setting variable P to a corresponding value. This can be helpful to introduce new transitive rules or replacing existing transitive rules. In the following, two example statements are shown. The first statement outputs all possible assignments for variable Y that render the statement true. In the first listing the empty set indicates that no rule is deactivated. The second example returns „false" since there does not exist a path from the telephone socket to MDF 1, if rule 4 is deactivated. The deactivation of rule 4 is evoqued by setting a set containing the string „rule4".

```
firstMile(telephoneSocket, Y, []).
Y = mainDistributorFrame2
Y = mainDistributorFrame1
```

```
firstMile(telephoneSocket, mainDistributorFrame1, [rule4]).
false
```

4 Conclusion and Future Work

This paper has presented a policy-based approach for First-Mile Routing. The approach uses first order logic to describe the policy rules which allows for elegant workarounds when parts of the inventory are unknown. It has been shown that the approach works on a high level network model. For simplicity reasons, no network constraints like total length and damping have been considered. However, the PROLOG code can be easily extended in order to find an optimal path through the First Mile considering those constraints. In a real world scenario, the network model is much more detailed and there are millions of network elements that have to be represented as logical facts. These facts have to be derived from the existing inventory. Additionally, the huge number of facts makes great demands towards the performance of the theorem prover. Those issues provide non trivial challenges and are subject of future research.

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