6 D − 2 Formulating International Telephone Network Management as Distributed Problem Solving

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1. Introduction

The Internationl Telephone Network Management (ITNM) is characterized by the following features:

(1) The overall network performance is influenced mainly by network operations in the gateway switches

(2) Each country can observe the status of the gateway switches, and that of direct routes which directly connect the country to others. The information about the other network elements outside the country however, is not accessible by any monitoring operation.

(3) Each country carries out network operation independently and asynchronously

ITNM can be veiwed as the behavior of a decentralized, loosely coupled collection of switches. The paper formulates Network Operations in ITNM as Distributed Problem Solving.

2. Basic Definition of ITNM

2.1. Network Elements

Network Elements of ITN is defined as a triple of $< D, S, R >$, where D is a set of *domestic networks*, S a set of *switches*, R a set of *routes*. Figure 1 illustrates a network structure as an example.

2.1.1 Domestic Networks

(1) Domestic network is a white circle in Figure 1, where D is a set $\{a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p\}$.

(2) Let $E_{x,y}$ be an average traffic from domestic network x to y. $E_{x,y}(x \neq y)$ is given as a part of the model, for $\forall x, \forall y \in D$.

(3) The dimension of $E_{x,y}$ is [erl].

2.1.2 Switches

(1) Switch is a black circle in Figure 1, where S is a set $\{A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P\}$. Switch is denoted in a capital letter corresponding to each domestic network denoted in a small letter.

(2) A switch selects a connection following the routing strategy shown by 2.2..

2.1.3 Routes

(1) Route
is a directed arc connecting two adjacent switches in Fig 1, where R is a set of $AB, AE, BC, BF, CD, CG, \ldots,$ $BA, EA, CB, FB, DC, GC, \ldots$

2.2. Routing Strategy of a Switch

Let $C_{x,y}$ be a call from domestic network x to y.

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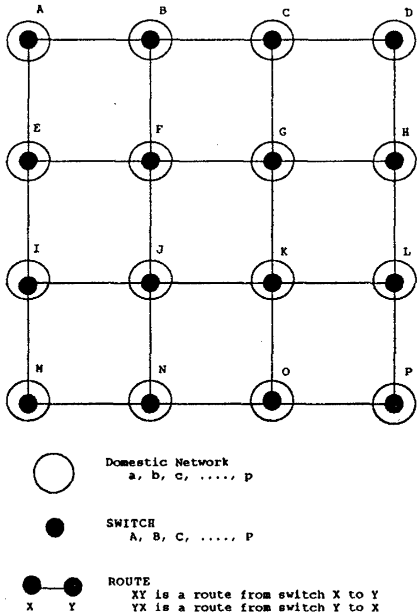

Figure 1: Network Model

2.2.1 Routing Algorithm

(1) If switch X accepts $C_{x,y}$ where X is a gateway switch from/to the domestic network x, and if X has the directly connected route to y,

(i) Find an available circuit from route XY.

(ii) If not found, check the availability of a route which consists of a path from X to Y in the order specified by the routing priority table (See Table 1) for switch X, excluding *route XY*. And find an available circuit in the chosen route.

(iii) If not found, $C_{x,y}$ is lost

(2) If switch X accepts $C_{x,y}$ where X is a gateway switch from/to the domestic network x, and if X does not have the directly connected route to y,

(i) Check the availability of a route which consists of a path from X to Y in the order specified by the routing priority table for switch X. And find an available circuit in the chosen route.

(ii) if not found, $C_{x,y}$ is lost

(3) If switch X accepts $C_{z,y}$ via route XZ from switch W, where X is a gateway switch from/to the domestic network x and Z is outside of x, and if X has the directly connected route to y,

(i) find an available circuit from route XY.

(ii) if not found, $C_{z,y}$ is lost

To	first	second
A	-	-
B	$< AB, V_{B,AB} >$	$< AE, V_{B,AE} >$
C	$< AB, V_{C,AB} >$	$< AE, V_{C,AE} >$
D	$< AB, V_{D,AB} >$	$< AE, V_{D,AE} >$
E	$< AE, V_{E,AE} >$	$< AB, V_{E,AB} >$
F	$< AB, V_{F,AB} >$ or $< AE, V_{F,AE} >$	-
G	$< AB, V_{G,AB} >$ or $< AE, V_{G,AE} >$	-
H	$< AB, V_{H,AB} >$ or $< AE, V_{H,AE} >$	-
I	$< AE, V_{I,AE} >$	$< AB, V_{I,AB} >$
J	$< AB, V_{J,AB} >$ or $< AE, V_{J,AE} >$	-
K	$< AB, V_{K,AB} >$ or $< AE, V_{K,AE} >$	-
L	$< AB, V_{L,AB} >$ or $< AE, V_{L,AE} >$	-
M	$< AE, V_{M,AE} >$	$< AB, V_{M,AB} >$
N	$< AB, V_{N,AB} >$ or $< AE, V_{N,AE} >$	-
O	$< AB, V_{O,AB} >$ or $< AE, V_{O,AE} >$	-
P	$< AB, V_{P,AB} >$ or $< AE, V_{P,AE} >$	-

Table 1: Routing priority table for Switch A

(4) If switch X accepts $C_{z,y}$ via route XZ from switch Z where X is a gateway switch from/to the domestic network x and Z is outside of x, and if X does not have the directly connected route to y,

(i) Check the availability of a route which consist of a path from X to Y with the first routing priority for switch X, excluding *route XZ*. And find an available circuit in the chosen route.

(ii) if not found, $C_{z,y}$ is lost

2.2.2 Routing Priority Table

Given the connection of switches as in Figure 1, each switch has the routing priority table. The routing priority table of switch A is shown in Table 1. $V_{Z,XY}$ is an evaluation of the goodness of the route XY for a destination switch Z.

2.3. Observability of Network Resources

2.3.1 Network Parameters

For the fault management of international telephone service network, CCITT[1] defines several parameters to estimate the status and performance of the network. ITNM assumes that every gateway switch makes real-time surveillance of those parameters. But the locally observable information is limited to the network elements directly connected to the observer switch.

2.3.2 Network Structure

In ITNM, creation/deletion of routes or modification of capacity of routes are made independently and asynchronously the related switches without notifying to the other switches. There is no automatic mechanism to maintain the map of network complete by keeping track of the individual network operations.

2.4. Manageability of Network Resources

2.4.1 Number of Circuits

Two adjacent switches can increase/decrease the number of available circuits. As this operation is made under the negotiation of the two adjacent switches, each of which can grasp the local network information concerning itself. Therefore the effect to other switches or routes is not always predicted properly.

2.4.2 Regulation of Call Acceptance

A switch can restrict the acceptance of incoming call circuit by circuit. Suppose that switch F has N_{FG} lines of circuits in the route FG, and a sudden increase of incoming calls from switch G to F. If most of the lines in route FG are occupied by the incoming calls from switch G to F, switch F cannot connect calls to switch G.

To save this situation, switch F can reject to accept incoming call to a part of the circuits, for example, circuit #10 to #20. Then circuit #10 to #20 is made usable only for accepting calls from switch F to switch G.

A switch can make this operation independent of other switches.

2.4.3 Routing Strategy

A switch can change the routing strategy to minimize the effect of the traffic problem. However, this may cause another serious problem, because the switch decides to do so based on the local information.

A switch can make this operation independent of other switches.

3. Problem Formulation

Davis[2] defines the concept of ***distributed problem solving*** as the cooperative solution of problems by a decentralized and loosely coupled collection of problem solvers.

Let us suppose

(1) that ITNM has a global goal such that "ITNM keeps the network performance as high as possible."

(2) and that the goal (1) is decomposed into a subgoal such that "each switch keeps the network performance which it concerns as high as possible."

Then the overall network operations in ITNM is formulated as a distributed problem solving by the switches in the network, where any cooperation is restricted to a pair of switches directly connected by a route.

Conry[3] describes a transmission path restoral in the telecommunication network as ***distributed problem solving***, where each agent is defined as a control authority within a site and able to modify routing with several network elements in the site.

In ITNM, switch is modeled as an agent who acts for the benefit of its domestic network. ITNM agent can control the acceptance of incoming calls (see 2.4.2) and its routing strategy (see 2.4.3). However, reflecting the nature of international telephone networks, ITNM is very different from Conry's problem formulation in the followings:

- ITNM agent should negotiate with other agent for creation/deletion of routes and modification of route capacity.
- ITNM agent does not have control over the domestic network which it belongs to.

4. Conclusive Remark

The paper gives the basic definition of ITNM, and shows that network operations in ITNM are formulated as *distributed problem solving*. ITNM is expected to provide a abstraction for theoretical analysis of integrated network operations.

References

[1] ITU, CCITT RED BOOK Volume II - Fascicle II.3, pp.5-81, 1985.

[2] Davis,R. and Smith,R.G.:"Negotiation as a Metaphor for Distributed Problem Solving", Artificial Intelligence Vol.20, No.1, pp.63-109, 1983.

[3] Conry,S.E., Kuwabaca,K., Lesser,V.R., Meyer R.A:"Multistage Negotiation for Distributed Constraint Satisfaction", IEEE Trans. Syst. Man Cybern., Vol.20, No.1, pp.1462-1477, 1991