Cloud to Multipoint: A Hybrid and High Available WAN Topology

Omid Aghalatifi, Majid Farahmand, and Pooya Tavosian

Abstract—**Central E-services have a key-role in enterprise governmental organizations. These organizations maintain related information in database servers inside one or more datacenters. Some of these organizations have a lot of country wide branches and all of them connect to datacenter(s) by WAN links. As a result to provide services with acceptable quality to customers, quality and stability of WAN links have main role. A usual method to achieve desired stability and availability is providing redundant link and running a suitable routing protocol over links to reduce service downtime of branches. This method has some constraints and drawbacks. The main constraint is lack of redundant WAN link in some regions. Also link and maintenance costs are two main drawbacks for this method. In this paper by combining existing WAN topologies we introduce a hybrid WAN topology with an acceptable stability and cost and predict availability of all existing methods and proposed models (C2MP) by aid of ITIL definition and prove at least by regarding stability, our model(s) have better result.**

Index Terms—**Availability, C2MP, ITIL, intranet**

I. INTRODUCTION

Nowadays, in Developing Countries providing services to their costumer is combined from centralized and local methods. This means that each organization with a lot of branches offers local services to local clients and at the same time can send\receive global information from datacenter(s) of organization. One of the main connection methods for accessing to centralized services from datacenter(s) is using WAN links. The branches provide services for clients with connecting to application servers that are located in central site. Connecting to datacenter and establishing services depended on the quality of WAN links of the organization and the final quality of service is directly based on type of topology and quality of establishing it. Availability of WAN links plays a vital rule in the quality of different WAN topologies. Some papers described routing protocols approaches to increase availability and employing redundant links for WAN links [1, 2]. Other approaches focused to quantifying datacenters availability regarding its components [3, 4]. Also, more information about analyzing WAN availability and its relation to the datacenter is referred by Aghalatifi et al. [5, 6].

Telecommunication service provider companies offer various types of these networks, based on different

topologies of WAN. If an organization selects a proper type, the appropriate quality and acceptable cost can be achieved. Also there is another approach to increase availability of connection: using redundant link and running routing protocol (RIP, EIGRP ···) over them. For example if a branch connects with both two different WAN methods to enterprise network, then by means of a routing protocol stability can be enhanced to an acceptable state. But if someone implements it in an enterprise organization with enormous branches, then link cost and troubleshooting for this network will be a challenge.

In this research, a smart combination of different types of network topologies is offered. Goal of this combination is to achieve more stability with proper cost. In this Paper, the prevalent topologies in Iran (Intranet and PTMP) will be described. Then, based on ITIL method and depending on statistical results in a period of one year, the stability of these topologies will be estimated. After that, a new combinational category with different subcategories named CTMP will be introduced. In this method, with proper combination of current topologies, more stability can be achieved; meanwhile, the cost can be reduced. It will be proved with the same method: ITIL. To evaluate our concept, we select an enterprise (SSOI) in Iran and all of our discussions extract from this enterprise.

In this paper, Section 2 considered existing and common WAN technologies that use in Iran and the hybrid model presented using them and in section 3, stability has been calculated for each type and has been compared in section 4. All terms, described rules and other concepts in this paper are considered for the SSOI (Social Security Organization of Iran).

II. WAN TOPOLOGIES

As described below, there are 2 main types of WAN topologies in SSOI: Intranet & PTMP (point to multipoint protocol):

A. Interanet

Intranet is a common connection type for wide area network in Iran [7]. This methodology transfers packets over general purpose routers in ITC and has a country wide vastness. Regardless of location of a branch in country, the charge of every link only depends on bandwidth. Ease of deployment is the most important factor for this links because this facility is feasible in almost all of the branches. "Cloud-base relation" is another benefit. It means if a branch gain access to intranet cloud, it can see every point inside it. This feature won't be considered as a main benefit because all branches deliver their services from SEDC (Fig. 1). But a

drawback for Intranet link is its availability. Undedicated bandwidth shared backbones and weak SLA impact quality and reliability of services. Branches connect to SEDC to access desired data and information and inaccessibility of connection means "no service".

B. P2MP

Due to definition, P2MP (Point to Multipoint Protocol) is a hierarchy model [7]. The branches in each province are connected to the province head office sites, and these headquarters are connected directly to the SEDC. Telecommunication switches and equipments compose physical layer for P2MP lines. Central points are connected to SEDC by aid of E1 (2Mb/s) links. So for each province we can divide P2MP into 2 sections: inter-province links (P2MP) and E1. Stability is main characteristic for primary section of link. Dedicated physical links lead to an acceptable quality in data transaction. In addition low cost is another advantage for this segment. Available bandwidth for inter-province P2MP satisfies requirements and has a range between 64-2048 kb/s. Next section referred to E1 links. This media uses telecommunication backbone and are more resilient against different disconnection issues than intranet, but less aspect to P2MP. Cost is a critical disadvantage for E1 and consists of annual charge, maintenance operation and equipments. Because all of the branches inside a province connect to SEDC from this link, so there is a single point of failure in P2MP topology and every corruption in central segment highly impact availability of services.
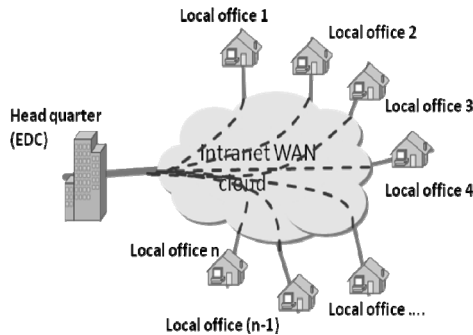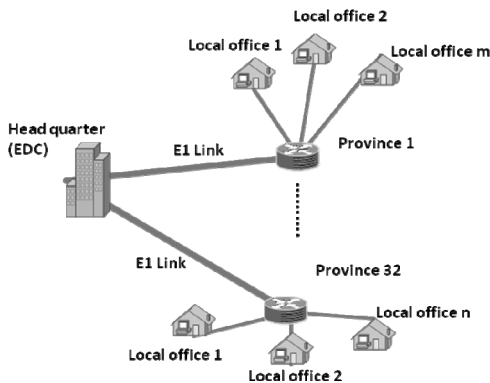

Fig. 1. Intranet cloud-base connectivity

Fig. 2. P2MP Topology

III. PROPOSED WAN TOPOLOGY MODELS

This section describes proposed WAN model with considerations in section III. The aim of proposed model is introducing a composed method to take advantage of two previous techniques. At first step we listed benefits of all links as described in Table I.

TABLE I: DIFFERENT WAN TOPOLOGIES AND THEIR ADVANTAGES

Intranet	P2MP (Inter-province)	E1
• Cloud-base • Cost • Implemantation • Globality • Troubleshooting	• High Availabilty • Dedicated lines • Low delay • Cost	• Moderate Availabilty • Bandwidth • Dedicated lines

According to previous section and our statistical monitoring data from 1000 branches in SSOI, in our method we used following supposition:

• P2MP links have high availability but lack of desired stability of E1 lines degrades our trust to P2MP topology.

• Intranet cloud has acceptable cost and can be employed in enterprise network as redundant links.

• Less complexity of router configuration in term of routing protocols is a goal.

Regarding our survey if we increase availability between centre of every province and SEDC, there won't need to redundant link in stub branches. Based on above subjects, we used a hybrid WAN topology composed from Intranet and P2MP that be named C2MP (Cloud to Multi Point) [8] and then expand basic proposed type and introduce 2 subcategories of it: star C2MP and hybrid C2MP. C2MP is same P2MP in concept but instead of a centralized point for joining points, we used several point in capital of each province and every cluster of inter-province cities connect to a central point (CP) (figure 3). The term "cloud" in our method refers to "all points that don't locate in centre of a province" .Due to our count in SSOI, average number of branches outside of capital of a province almost is two times greater than CPs. So shown state for every cluster in figure 3 is a real state.
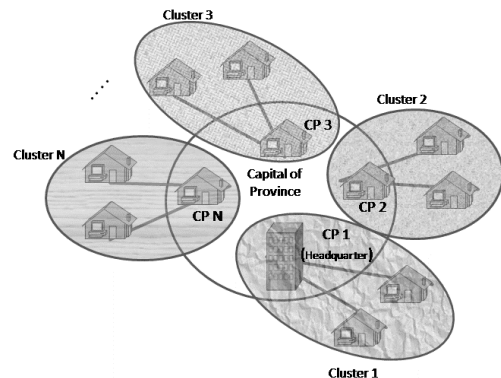

Fig. 3. Inter-province topology in C2MP

To connect CPs to enterprise WAN cloud, two approaches were introduced:

• Star C2MP: All CPs (including Headquarter) will connect to Intranet cloud so they can gain access to SEDC, as depicted in figure 4. Although cost saving is a benefit of this method, but loss of redundant link for CPs is a main drawback. This problem impacts availability and can creates serious challenges.

• Hybrid C2MP: The previous method can be enhanced

by insertion of redundancy for CPs. In this method, we used star and tree topology together. In the star C2MP we connect all of the CPs to headquarter and then to SEDC by an E1 link (figure 5), it means in this scenario there are two parallel paths. Appling this method will omit single point of failure BQand will increase reliability. This method is simplest hybrid model and by composing different topologies model, availability will be increased. For example another hybrid concept can be created by mixing ring and star topologies, every CP connects to its neighbour and all of the CPs have their intranet link. But this method will be so expensive and didn't be considered in this paper.
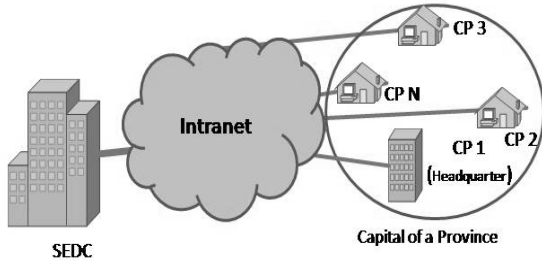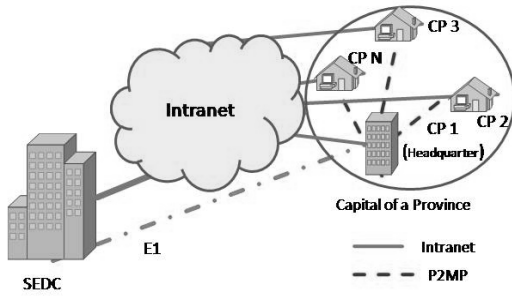

Fig. 4. Star C2MP approach

Fig. 5. Hybrid C2MP approach

• Hybrid C2MP, Star & mesh: This model is the final hybrid WAN model and has higher complexity. As will be seen in next section, this model has a high availability. In this WAN configuration all of the CPs (including headquarter) will connect to each other by using a mesh connectivity (figure 6). Because all of the CPs are in a city, it is possible to connect them by fibre optic media and achieve a high stability and bandwidth. Also all E1 line (from headquarter to EDC) can be replaced by Intranet lines and in this way total topology cost will be decreased. Although the complexity of this model is a little more than the previous one, but in case of availability, this will be an acceptable option.
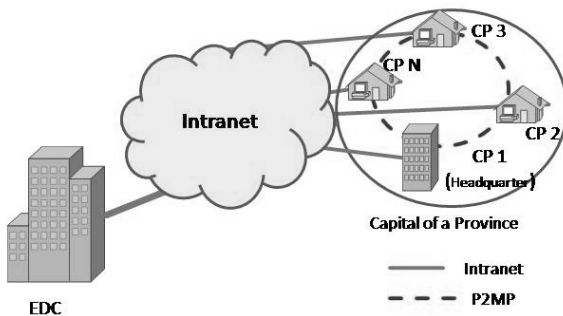

Fig. 6. Hybrid WAN type: Star and Ring toplogies

IV. AVAILABILITY ESTIMATION

This section analyses availability for proposed WAN topologies regarding Intranet and P2MP by aid of ITIL definition for this parameter. According to ITIL definition, availability is the ability of an IT service component to perform its required function at a stated instant or over a stated period of time and expressed as percentage. Basic formula for availability calculation is [9],[10]:

$$\frac{\text{Agreed service time-downtime}}{\text{Agreed service time}} \cdot 100$$

Availability of a complex ("A_v" stands for "Availability"):

- For n serial components: Availability only, if all are working= $A_v(1)\, A_v(2) \cdots A_v(n)$;
- For n parallel components: Availability=1−not availability= 1−all failing=1−[(1−$A_v(1)$)(1−$A_v(2)$) ⋯(1−$A_v(n)$)].

To calculate availability, we define a number of effective parameters in the Table II.

TABLE II: USED KEY CONCEPTS IN THE ANALYSIS

Key Concepts	Representative
Intranet availabilty	A_{vI}
P2MP availabilty	A_{vP}
E1 availabilty	A_{vE}
Fiber optic availabilty	A_{vF}
Average number of branch in a province	n
Average number of branch in capital of a province	$m \approx n/3$

At this point, by aid of ITIL we estimate link availability for each topology in a sample branch and in a province.
• Intranet: Intranet is a direct link so availability is a single parameter and is equal to A_{vI}.

To identify effect of link disconnection in all branches in a province, we present new criteria and named it as "not absolute inter-province branches downtime" or "not absolute unavailability" as following definition (P represents as probability function):

P(not absolute unavailability)=P(at least one branch in desired province isn't down)

For Intranet topology, these criteria are calculated as follow:

P(not absolute unavailable) =
1−P(all intranet links be down)=1− $(1-A_{vI})^n$ (1)

• P2MP+E1: For this model, both P2MP link and E1 must be connected to deliver service from SEDC to branch office. So a sequential conditions combine availability and will be stated as follow:

A_{vP+E} = Availability (Sequential links)
P(availability of a branch)= A_{vP+E} =$A_{vP}A_{vE}$ (2)

Because downtime of E1 means disconnecting of all inter-province offices, so:
P (not absolute unavailable) = P("E1 be available" and " at least one P2MP be available")= $Av_E \times (1-(1- Av_P)^n)$ (3)
• Star C2MP: As described, this model is mixed from

P2MP and Intranet link of a CP. So two sets of branches contribute in the scenario: CPs and other branches. We estimate availability individually for two sets of branches:

$$P(CP) = \text{Availability (Intranet links)} = Av \quad (4)$$
$$P(\text{Others}) = Av_I \times Av_P \quad (5)$$

In this model absolute unavailability of a province obtain from a different aspect of view:

P (Absolute unavailability) = P(all branches be down)

$= (1- Av(CP)^m)*(1- Av(\text{Others})^{n-m})$

where m is number of CPs. By equalization from Table II ($m \approx n/3$):

P (Absolute unavailable)= $(1-Av(CP)^{n/3}) \times (1- P(\text{Others})^{n-n/3}) = (1- Av(CP)^{n/3})\ (1- P(\text{Others})^{2n/3})$

And finally we will have:

P(not absolute unavailable)= 1- P (Absolute unavailability)

$$= 1-(1-Av(CP)^{n/3}) \times (1-Av(\text{Others})^{2n/3})$$

$$= 1- (1- Av_I^{n/3}) \times [1-(\ Av_I] \times\ Av_P)^{2n/3} \quad (6)$$

• **Hybrid P2MP:** In hybrid models different topologies can be mixed together, and in this research we estimate availability for tree and star mixture. Same previous one, two sets of offices contribute in this type: CPs and "other" branches (branches in cities except the capital of province). We partitioned our calculation in two groups: "unavailability for a branch" and "absolute unavailability for a province". According to this segmentation, for first part we have:

$$P(CP) = P(\text{"Intranet be available" or "P2MP} \times \text{E1 be}$$
$$\text{available"}) = 1- (1-Av_I)\times(1-Av_{P+E})$$

$$P(CP) = 1-(1-Av_I)\times(1-Av_P\times Av_E \quad (7)$$

P(others)=P("P2MP be available" × "("Intranet be available" or "P2MP × E1 be available"))= $Av_P \times Av(CP)$

$$P(\text{others})= Av_P \times[1-(1-Av_I)\times(1)]\ Av_P\times Av_E \quad (8)$$

To calculate for second one, we consider this fact that if a CP be disconnected, so all (two) other related branches to it won't deliver service from SEDC. As a result to estimate "not absolute unavailable" probability, connection of only one CP satisfies condition:

$P(\text{not absolute unavailable})=1-P(\text{all CPs be down})=$
$1-P(\text{CP}_1 \text{ be down}) -\cdots -P(\text{CP}_m \text{ be down})$
$= 1-[1-A_v(CP)]^m$

From Eq. 7, we have

$P(\text{not absolute unavailable})$

$$=1-[1-(1-(1-A_{vI})\ (1-A_{vP}\times A_{vE}))]^{n/3} \quad (9)$$

• **Hybrid P2MP, star and ring:** The contributed parts in this scenario are CPs and "other" branches. We supposed that the media for inter-city ring connectivity is fiber optic. So we introduce A_{vF} as "fiber optic link availability". Each CP connects to its two neighbours by fiber optic. We calculated "unavailability for a branch" and "absolute unavailability for a province". So we have:

P(CP) = P("Intranet be available" or "Fiber media to 2 neighbours and Intranet of the neighbours be available")

$= 1- (1-Av_I) \times(1-Av_{F+I})_{\text{neighbour 1}} \times(1-Av_{F+I})_{\text{neighbour 2}} = 1- (1-Av_I) \times(1-Av_F\times Av_I)_{\text{neighbour 1}} \times(1-Av_F\times Av_I)_{\text{neighbour 2}} \quad (10)$

P(others)=P("P2MP be available" × "("Intranet be available" or "Fiber media to 2 neighbours and Intranet of the neighbours be available "))= $Av_P\times Av(CP)$

P(others)= $Av_P \times (1- (1-Av_I) *(1-Av_F* Av_I)_{\text{neighbour1}} \times(1-Av_F\times Av_I)_{\text{neighbour 2}}) \quad (11)$

For the second part, we supposed unavailability of a CP means "no service" for two "other branches". The calculation method is like "star and tree hybrid model" and described as below:

P(not absolute unavailable)= 1- P(all CPs be down)

= 1- P(CP1 be down)×…P(CPm be down)

= 1- $[1-A_v(CP)]^m$, from Eq. 10:

P(not absolute unavailable)=1-$[1-(1-(1-Av_I) \times(1-Av_F\times Av_I)_{\text{neighbour 1}} \times(1-Av_F\times Av_I)_{\text{neighbour 2}})]^{n/3}$ (12)

TABLE III: VALUES FOR PARAMETERS

Key Concepts	Availability	Representative
Intranet	97%	Av_I
PTMP	98.7%	Av_P
E1	98.5%	Av_E
Fiber optic	99.997%	Av_F

TABLE IV: AVAILABILITY NUMERIC VALUES FOR A SINGLE BRANCH

Topology	CP	
	Eq. No	Num. Value
Intranet	1	99.4%
P2MP	3	98.5%
Star C2MP	6	97.58%
Hybrid C2MP: star & tree	9	99.99%
Hybrid C2MP: star & ring	12	99.9999%

TABLE V: NOT ABSOLUTE UNAVAILABILITY NUMERIC VALUES INSIDE A PROVINCE

Topology	CP		Others	
	Eq. No	Num. Value	Eq. No	Num. Value
Intranet	-	97%	-	97%
P2MP	2	97.22%	2	97.22%
Star C2MP	4	97%	5	95.74%
Hybrid C2MP: star & tree	7	99.917%	8	98.61%
Hybrid C2MP: star & ring	10	99.997%	11	98.69%

V. RESULTS

This section will demonstrate numeric results based on our practical measurements. By watching annual down time and unavailability of the different WAN links, we verified availability values for used type in our proposal. WAN link availability measurement was performed by "Orion Solarwinds" software, an enterprise and well known software in network monitoring systems. As described in the previous sections, there are 3 different kinds of WAN links in our connectivity topology. Brief availability values for the WAN

links in different scenarios are listed in Table 3. For second group, estimations are shown in Table 4. As been demonstrated in the Table 4 and 5, the best availability is gained from Hybrid C2MP models. But for first proposed model, star C2MP, there is another story in availability ranking and it hasn't acceptable state. But P2MP has better view than it and can be considered as a solution.

VI. CONCLUSION AND SUGGESTIONS

In this paper we analyzed different WAN topologies type in Iran and introduced a new category of WAN topology to gain higher performance and availability. By observing an enterprise in Iran (SSOI), we evaluate numeric value for availability criteria.

The objective behind studying implementable scenarios is connecting branches to datacenter in a reliable model over existing WAN links. There are different approaches to gain better availability (for example implementing routing protocols) but considering low cost and maintenance overhead, we proposed a new category of P2MP model that be called C2MP.

Our proposed method can be formed to different types and in this paper we verify star-C2MP, Hybrid Star & Tree-C2MP and Hybrid Star & Ring-C2MP. By aid of ITIL, numeric estimations showed better performance in case of availability. Our Experimental results can be applied for other enterprises. Also enterprises can realize application scalability and high availability and increased redundancy for new application by increasing WAN reliability and deploying proposed methods in datacenter distribution schemas [5]. Result of this paper lead us composing different WAN types can gain better availability.

For further study, we suggest cost be considered to prepare a comprehensive solution for planning architecture of enterprise datacenters for organizations, especially while considering fiber optic as a WAN solution, primary cost of method will increased but more 5 nine (99.999..%) availability will compensate implementing charges in long term services delivery.

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