Transformation of PSTN to Next Generation Network

The approach and implementation by Chunghwa Telecom

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Abstract—**Transformation of PSTN to NGN is a challenging goal for many legacy telecom operators. A smooth migration for PSTN will be an evolutionary process. It is expected that a new generation PSTN can extend the range of new services. Chunghwa Telecom is currently initiating an NGN_CN development which is part of NGN project for PSTN migration. In this paper, the key network technologies for PSTN migration are studied and NGN_CN network architecture is depicted. A three-stage PSTN migration process is proposed for legacy PSTN switch equipment replacement. The key routing issues for network migration are identified and a centralized routing architecture across service domains is proposed. An innovative service convergence architecture which integrates NGN_CN, Internet, and smart mobile devices is implemented for enhancing future PSTN services.**

Keywords— IMS; NGN; PES;

I. INTRODUCTION

For many years conventional Public Switched Telephone Network (PSTN) has proven its traits of high reliability and service quality. However, facing fierce competition from IP technologies, it is apparent that PSTN needs to migrate to an IP-based converged network to increase its competitiveness. This will be a challenging paradigm shift for many telecom operators worldwide. Although each telecom operator may have different operation environments or business concerns, a common and inevitable direction is to evolve PSTN to an IP based multi play (M-play) converged services network.

The driving factors for the transformation of PSTN are summarized as follows:

1) Competition concerns

- Internet telephony is prevalent and has made a dramatic impact on fixed network voice revenue, especially on the long distance voice revenue and international voice revenue.
- More and more ICT services are developed on the Internet due to its nature of openness. PSTN therefore needs new services with differentiation.

2) PSTN retirement concerns

- For many PSTN operators, as their legacy circuit switches typically have been put in service for over 20 years, they need to consider the issue of replacement to keep existing services. The decision options are either to adopt conventional circuit switch or to adopt new generation switching technology to evolve to an IP packet network infrastructure.
- Although in a conventional PSTN there is usually an intelligent network service platform for creating/deploying new services, its openness and flexibilities in new service creation are still quite limited compared to Internet environment. It therefore requires a more flexible network environment to create value added services so as to meet the customers' needs.

3) Network operation concerns

- The new deployed network calls for easy maintenance, reduced CAPEX/OPEX , and a converged centralized network management

Chunghwa Telecom (CHT) is an integrated telecom operator in Taiwan and is currently migrating its PSTN to NGN (Next Generation Network). In the recent years it has initiated an NGN Core network (NGN_CN) development, which is part of NGN project for PSTN migration. The ultimate goal is to build an M-play converged services network.

In this paper, the designed NGN_CN network architecture is depicted based on the analysis of standard technology options. The migration steps are then proposed for legacy switch equipment replacement. During migration, call routing issues are identified and solutions are designed. Finally, an innovative services convergence architecture which integrates NGN_CN, PLMN, Internet, and smart mobile device is proposed and elaborated. It is also expected to enhance future NGN_CN services.

II. DEVELOPING NGN_CN

CHT is developing a converged NGN network, which is an IP based network and will accommodate POTS (Plain Old Telephone Service) services, multimedia services, high speed Internet services, IP TV services, and converged services. NGN_CN is the part of NGN to replace legacy PSTN services. In this section we will introduce the design of CHT NGN_CN.

A. ASPECT of CHT NGN

The purpose of NGN is to provide a variety of new services while continuing to support the provision of legacy services. Based on ITU-T NGN definition, an NGN is a packet-based network which is able to provide telecommunication services and is able to make use of multiple broadband, QoS (Quality of Service) enabled transport technologies [1]. The service-related functions are independent from underlying transport-related technology. The function of NGN can be divided into service stratum and transport stratum.

The design philosophy of CHT NGN follows the concept of layer design. Network design based on the layer concept can make future network development to be more open and flexible, especially in a multi vendor environment. CHT NGN architecture is shown in Fig. 1.

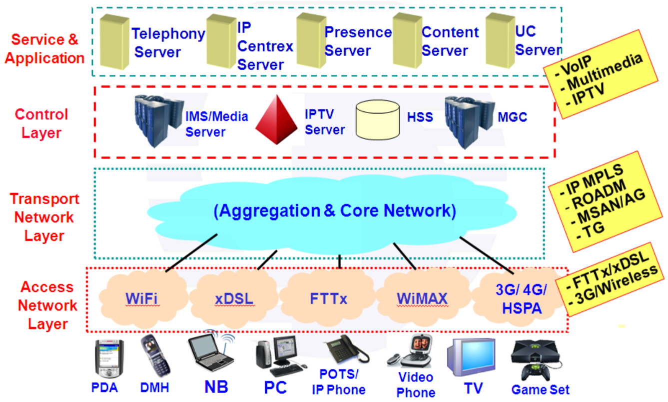

Figure 1. NGN architecture of CHT.

In the access layer, multiple access networks will be connected to NGN. The traditional copper lines are still required for POTS/ISDN services. Broadband accesses, including xDSL, FTTx, and broadband mobile are accommodated.

In the transport layer, the IP edge node and core node will be interconnected through high speed optical switching network.

As to the service control layer, this layer will be responsible for session control, call control, and media control for different services. Specifically, for new PSTN service control, that will include media gateway control (MGC) element or IMS (IP Multimedia Subsystem) service control element [5]. In the service layer the POTS, IPTV, and a few innovative IMS-related value added services are already designed and are in commercial operation. Some converged services are being developed.

B. *Designing NGN_CN ARCHITETURE*

NGN_CN is designed for PSTN switch replacement and for multimedia services. Traditional PSTN services are for POTS service and will be provided. To realize POTS services in NGN, ITU-T defined two approaches for realization of new generation PSTN. They are PSTN/ISDN simulation service and PSTN/ISDN emulation service (PES) [2].

For PSTN/ISDN simulation service approach, the multimedia services and PSTN-like services with most POTS features will be introduced. For the multimedia services, the user equipment may be an IP based device, such as video phone, IP phone, personal computer with soft client. For supporting PSTN-like services, legacy phone through terminal adapter can also be connected to the network. However, there are some traditional Class 5 switch service features that could not be realized due to architecture and protocol limitation.

PES approach can be adopted to replace legacy PSTN/ISDN switching equipment while allowing POTS/ISDN services to be still provided, even with unchanged legacy terminal. Customers will not be aware of any service changed.

However, with PES approach, ITU-T further defines two architectures to realize this service: the call server (CS) based PES and IMS based PES [3] [4]. IMS is a service framework by 3GPP (3ird Generation Partnership Project) to provide multimedia services independent of access network [5]. IMS has flexible service trigger capabilities and is considered to be a very important service framework for future convergence services worldwide.

With CS based solution, it resembles traditional circuit switch architecture, but decomposes conventional circuit switch equipment into a distributed fashion. The key control component of CS solution realized by industry is generally a softswitch, which is to process the call control and basic service features. Softswitch is similar to the call processor in legacy switch equipment. The POTS service feature functions are tightly coupled with softswitch.

Using IMS based PES, the switch call control and service feature functions will be separated into two parts of function entity, namely, the AGCF (Access gateway control function) and IMS with application server function entity. IMS is responsible for session control and service control. This approach will have the potential to let IMS based architecture support both POTS and broadband multimedia services simultaneously and have a more consolidated architecture for both services.

Table 1 below summarizes the differences between these two kinds of PES we made, which indicates that IMS PES would have better consolidation architecture in terms of service across simulation service domain, routing information management, and common resources utilization.

TABLE 1 COMPARISON OF CS- BASED AND IMS- BASED PES

	CS-based PES	**IMS-based PES**
Core network architecture aspect	Consists of two different network architectures	One unified IMS architecture, potentially one single OSS system
Location of Service feature function	Embedded in each softswitch, and uneasily develop new services	Services logic resides on application server, easily develop new services across CS and IMS domain
Routing information management efficiency	Routing information is distributed in softswitch, more complex to adapt to network change	Centralized routing can be used, and easily to adapt to network change
Utilizing Common resources	Less likely	More likely

Although IMS PES has better architecture for PSTN transformation, yet most switch vendors currently support CS based PES, which inherits a lot of legacy switch design and service feature function. Therefore, to be pragmatic, we decide to adopt CS based architecture as a solution in the first step to retire legacy switches. Once industry IMS PES products are proved to be mature, IMS PES solution will then be adopted.

Except for switch replacement just mentioned above, Another purpose of NGN_CN is to support multimedia services. IMS architecture is adopted as the technique solution. After NGN_CN is deployed, it is very likely that some customers might need multimedia services while some customers still want to keep their POTS services. Therefore both requirements need to be considered when developing NGN_CN. Fig. 2 shows the designed NGN_CN network architecture. All service elements are interconnected through a managed IP network with QoS control. There are two kinds of service domains to be supported, i.e., PES services domain and IMS services domain (or PSTN/ISDN simulation services domain).

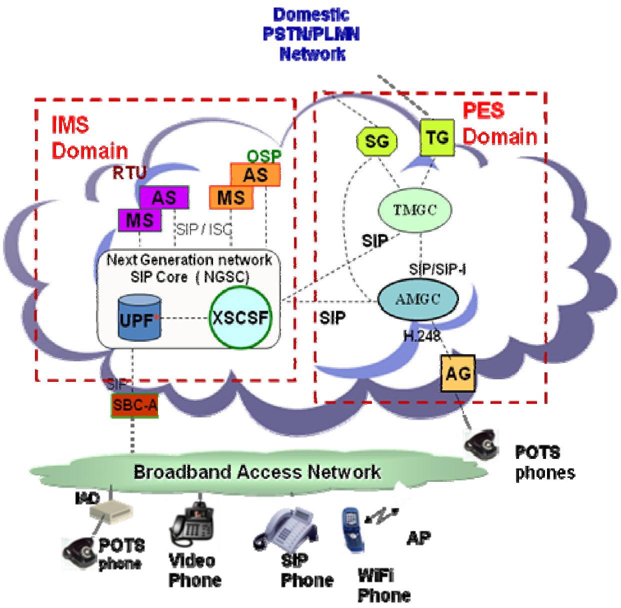

Figure 2. NGN_CN architecture.

The PES domain network consists of AMGC (Access Media Gateway Controller) Controller, TMGC (Trunk Media Gateway Controller), SG (Signaling Gateway), AG (Access Gateway), and TG (Trunk Gateway). AMGC is responsible for call control function of AG while AG provides legacy voice services and performs voice coding/decoding conversion. AG is connected to legacy POTS phone. TMGC controls interconnection with legacy fixed or mobile networks. TG is controlled by TMGC and is used for voice media conversion between TDM voice and packet voice and is directly connected to TDM trunk. SG is a signaling bridge point between legacy network and PES network.

In the IMS domain network, the multimedia convergence services (MCS) are provided. NGSC (NGN SIP core), AS (application server), and MS (media server) are the main network elements in this domain. NGSC will perform the IMS related access control, session control and media control functions and handle the database of user profile. The SIP (Session Initiation Protocol) is adopted as the session control protocol for multimedia services. AS plays the role of the value added service platform. There are two types of AS, i.e., ready to use (RTU) platform and open service platform, to be provided. RTU platforms are service platforms providing commercially ready value added services, such as IP Centrex service, while open service platform is for new service creation and execution. MS is used for handling interactive response of voice or video media and playing announcement.

At the customer sides in IMS domain, users can use MCS CPEs, such as video phone or IP phone. However, if a customer still wants POTS-like service, the legacy phone can be connected through an IAD (Integrated Access Device) device for service adaptation.

III. TRANSFORMING PSTN

In NGN_CN there are two type of networks adopted for PSTN transformation: one is PES domain for legacy switch replacement and POTS service, and the other one is IMS domain which will mainly provide customers with new multimedia services or PSTN - like service.

In addition to employing the AG to accommodate legacy POTS phone transferred from legacy PSTN, there are two alternative approaches for transferring POTS subscriber who have broadband connection. If a broadband subscriber still wants to use POTS phone with limited service features, the legacy phone can be connected to the IAD. Otherwise, CHT will encourage subscribers to switch to the MCS CPEs with multimedia capability. Which of these two approaches shall be taken depends on the customers' preference.

We propose PSTN switch replacement process and proceed in three stages, as shown in Fig.3, Fig.4, and Fig.5, respectively. Customers will have the options to choose POTS service or MCS service. It is estimated that at least 10 years is required to complete a full transformation.

A. *Initial stage: local switch (LS) replacement*

- Replace aged LS (typically exceeding 18 years' operation and requiring much maintenance efforts) in the initial stage. In NGN_CN, AGs accommodate those subscriber lines that are being moved out from those aged LS of PSTN. The other option for customer is to switch POTS service to MCS service.

- Because both PSTN and new developed NGN_CN will co-exist, it requires deploying TGs to connect these two domains of networks so that the subscribers on each network domain are able to communicate each other. The capacity of Trunk Gateway (TG) required depends primarily on the traffic flow between the two network domains.

B. *Transit stage: Tandem and Toll switch replacement/ reorganization*

- At this stage more and more aged LS switches of PSTN will be replaced and subscriber lines will be transferred to NGN_CN. The tandem/toll switches within each charging area with less LS connected or with less traffic will be replaced or reorganized. The network and transmission trunks are to be reorganized to allow more efficient utilization of network resources. Between the legacy PSTN and NGN_CN, voice traffic will increase due to that fact that more LS are replaced and moved out to NGN_CN, and the required number and capacity of TGs will consequently increase.

C. *Final stage: Full PSTN transformation*

- When all subscriber lines of the CHT are transferred from legacy PSTN to NGN_CN, CHT's new PSTN is a fully packetized network. There will be no tandem or toll switch exist. It will not require TG in the internal NGN_CN network. However, for interconnection with other carrier's network, TG will be employed as the interconnection point, as other carrier's network (e.g., fixed or mobile) might not have been packetized yet.

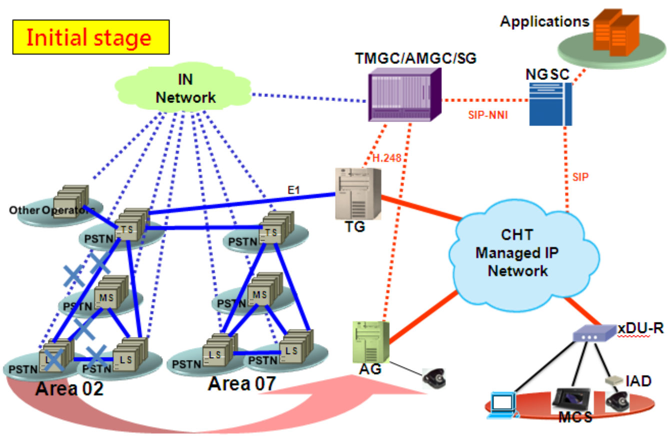

Figure 3. Initial stage of PSTN transformation.

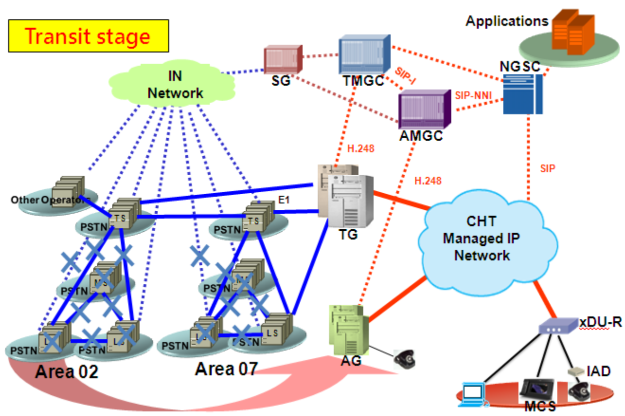

Figure 4. Transit stage of PSTN transformation.

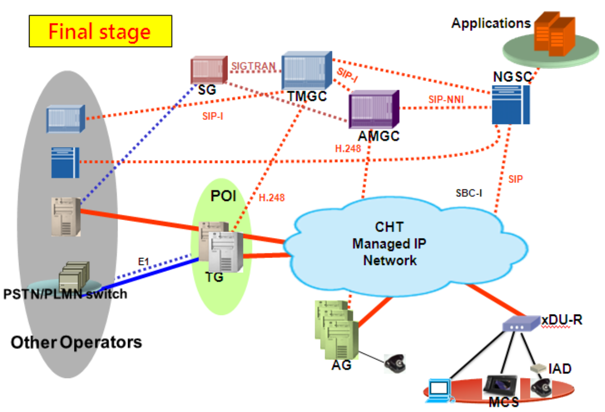

Figure 5. Final stage of PSTN transformation.

When PSTN is migrated to NGN_CN, three schemes are employed for provisioning NGN_CN services depends on customers' preference. They are the AG scheme for legacy POTS service, IAD scheme for PSTN–like service, and MCS scheme for multimedia services, respectively. The guideline of the provisioning scheme selection is shown in Fig.6 and described as follows:

- If the subscriber does not have broadband network connection, the requested service can only be provisioned through AG scheme.

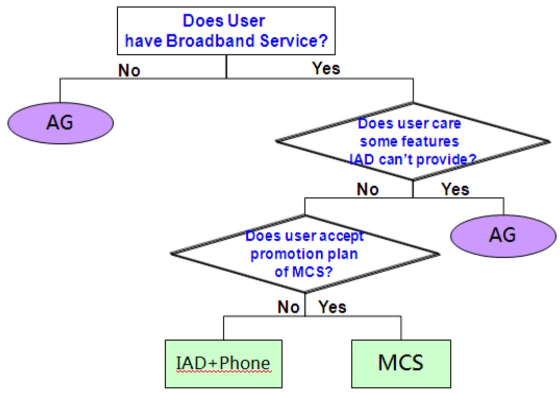

Figure 6. Provision guideline for NGN_CN

- If the subscriber has broadband connection but still insists on the use of traditional POTS services, it will use AG for installation. Otherwise, subscriber has the option to choose IAD scheme for POTS service or MCS scheme for multimedia service.

IV. Routing Issues

Call Routing will be a challenging task for PSTN transformation of CHT. Before PSTN migration has been fully completed and is in the transition stage, CHT's PSTN network can be considered as a combination of three sub networks, i.e., legacy PSTN, IMS service domain, and PES service domain. The main issue is which service domain the users are served and network how to route their call. The users may be served in one of these service domains, respectively. In such a case, how to route a call to correct destination will be an important issue and need to be solved. Currently, there is no standard body to address this issue for this type of PSTN transformation. Two schemes are designed by CHT. They are redirect scheme and centralized routing scheme.

For the Redirect scheme, the call first will be routed to the called party's originally located legacy local switch if this legacy switch has not been replaced, or PES domain if legacy switch is replaced), then the original switch or PES domain look up the routing table and based on the routing information to re-route the call to the actually located service domain network if the called party is served in IMS service domain. In this scheme, this will burden the original switch to process call. The number of routing table entry in switch typically have its limitation. Furthermore, the call will experience a longer signaling path compared with a legacy normal cal and incur call performance to have a longer call set up time. Also, the voice media will also experience a longer path which consumes more network resource of circuit switch trunk path and packet switch connection path, and results in increasing network service cost.

For the centralized routing scheme, a centralized routing table and query mechanism is required to provide route decision function and find the correct service domain of called party immediately. Based on centralized routing, it can provide most efficient routing solution among three service domain networks. It also can solve the performance and cost issues that may encounter in the redirect scheme.

In the initial PSTN migration stage, redirect scheme is applied to have less impact to current existing network operation. Centralized routing scheme is planned as the long-term goal for CHT. To interoperate with three service domain networks, standard ENUM based architecture is adopted as the core of centralized routing scheme, as shown in Fig.7. E.164 NUmber Mapping (ENUM) standard translate a telephone number into a Uniform Resource Identifier (URI) that can be used in Internet communications [6] [7] [8]. In the centralized routing server, it will provide routing table to provide correct routing information for three service domains. The protocol defined by ENUM is adopted between centralized routing server and IMS service sub network. For the legacy PSTN domain and PES domain, the INAP (Intelligent Network Application Protocol) follows the signaling of intelligent network is adopted as the routing table query protocol. To this end, an interworking function is designed in the centralized routing server to provide INAP and ENUM protocol conversion. This proposed architecture has been proved to be feasible and a commercial implementation is ongoing.

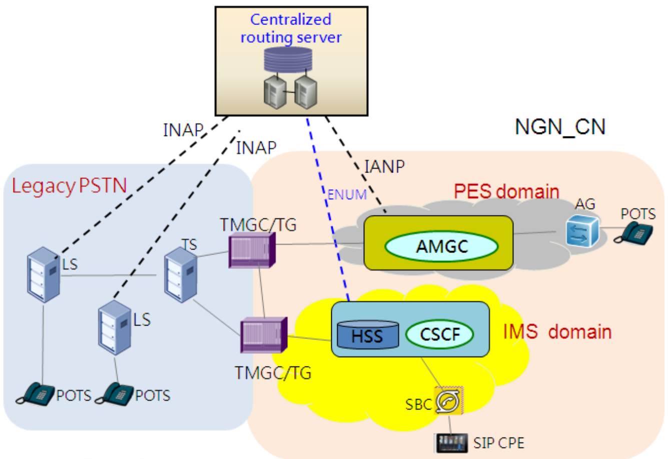

Figure 7. Provision guideline for NGN_CN

V. SERVICE CONVERGENCE ARCHITECTURE

As mentioned in earlier section, developing a full IMS-based NGN which can support both PSTN emulation and PSTN simulation services will be the ultimate goal in PSTN transformation. IMS has the capability of flexible service trigger and support diverse multimedia services in addition to voice conversation. However, from CPE point of view, current typical IMS-based CPE that has been developed in the industry did not catch the trend and thus did not attract much attention compared with prevalent smart mobile devices, such as tablet or mart phone. Indeed, famous for its excellent user interface and strong App market support, the smart mobile device highly appeals to most telecom customers. Therefore, the smart mobile device can never be neglected and should be efficiently utilized to provide synergy when approaching new generation of PSTN and Internet convergence. The service convergence architecture we proposes and under development is based on the combination of PSTN /PLMN communication, Internet/cloud IT services, and smart mobile devices.

The smart mobile devices, especially smart phone, has the characteristic to combine the telecom CT (Communication Technology) capability and the IT (Information Technology) functions in one terminal. Though multiple networks can be accessed in a smart phone, e.g., 2G/3G/GPRS/HSDPA/WiFi, basically two categories of service access approaches can be identified, the telecom network approach for voice service and the Internet approach for data or IT services. In most cases, these two approaches never intersect from devices point of view and separate client software execution independent of each other in smart mobile device. People currently get used to download Apps from App markets and execute them locally or connect to App servers in Internet. Thus, the App downloading or execution on smart devices contributes just data traffic over the dumb pipe to telecom operators. How to integrate the CT and IT capability of mobile devices or integrate the CT capability of POTs phone and IT capability of smart device, and generate interaction between CT/IT capabilities requires a mediation architecture in the network, which can potentially increase the value added services for PSTN or PLMN. Based on this idea, an innovative IT and CT service convergence architecture is designed and implemented to leverage the PSTN/PLMN network capabilities, Internet/Cloud, and smart devices simultaneously, which is depicted as in Fig.8.

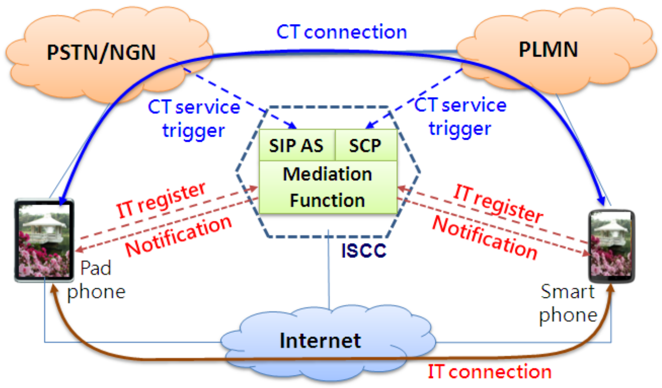

Figure 8. ICT service convergence architecture in NGN_CN

Among the PSTN/NGN_CN, mobile network, Internet/Cloud, and mobile devices, an ICT Service Convergence Center (ISCC) is established to act as a mediation function bridge between IT and CT domain. ISCC consists of SIP application server (AS) or Service Control Point (SCP) function, and a mediation function entity. For the user side, it can just use smart mobile phone or use both legacy device (e.g., POTS phone) and mobile device (e.g., tablet). A newly developed App software for service convergence is installed in the smart device in advance. Smart device will register itself to the ISCC upon enabling the ICT service convergence function.

When any call connection request related to a service convergence user (user may belong to NGN_CN or PLMN) is initiated, voice network will trigger it to AS or SCP. AS/SCP will analyze and signal the mediation function. Mediation function entity then notifies smart mobile device to initiate corresponding IT application related to Internet or Cloud. The call connection event will be processed simultaneously in CT domain and completed in the normal call connection process. In such a way, the IT connection and the CT connection can be correlated and potentially generate more value added services. In the following sections, a service prototype example is presented to reveal the effect of the proposed service convergence architecture.

For a typical PSTN/NGN_CN call using the POTS or SIP phone in a network without service convergence, the incoming call number can just be displayed on a small panel of the phone set. However, the displayed number brings little information if it is not familiar by the called party. Using the service convergence architecture we propose by integrating some information system in IT domain, the incoming call display service can significantly improve the user experience.

Fig.9 shows a caller information display service prototype for a user with POTS phone call a user with Pad phone. When a Pad phone connects to NGN_CN, it will first register its phone number to ISCC to generate CT and IT correlation for this phone number. When an incoming call reaches the Pad phone, the convergence App in the Pad can be initiated and query the database in Internet, and display the detailed information about the caller's phone number. The other scenario is if the called party use POTs Phone and simultaneous with Tablet in hand and wants this kind of service. The voice communication can proceed in POTs phone, and caller information can display on Tablet through a combination of both devices. This is because the CT capability of POTs phone is correlated with IT capability of Tablet through the same process described above.

According to the database queried, various kinds of information can also be provided to extend the application scope. For instance, if the Customer Relationship Management (CRM) system is used for an enterprise, the incoming call belonging to the customers of this enterprise can show the customer related information, like orders and transaction history, to the called party. It can also be applied to Personal Information Management (PIM) system which stores personal contact information on the cloud. Any incoming call matched with PIM can be pre-identified while the unknown number can also be added to the contact list right away. Furthermore, the database of anti-defraud phone number can also be used to hint the called party that the incoming call might be a fraud call before answering it.

Based on the proposed ICT service convergence architecture, many up-to-date Internet applications can be incorporated into the telecom networks. The value of the architecture not only relies on new services introduced through smart device, but also encourages the 3rd party application developers devoting to creating the new style of ICT services.

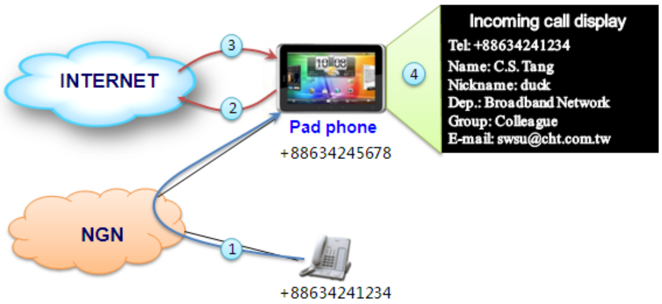

Figure 9. Incoming call display: a ptototype of service convergence

VI. Conclusion

CHT's PSTN is in the process of being migrated into IMS based NGN_CN. An evolutionary three-stage migration process approach is adopted to guarantee smooth service migration. The proposed centralized routing solution are to be implemented for routing call between legacy PSTN and NGN_CN.

Currently, an NGN_CN has been implemented to replace some aged legacy switches. To assure service quality, especially for FAX service quality, a systematic testing method is the future work to proceed. Network virtualization technique for IMS network is the next research topic to make network development more cost effectively.

To leverage the IT capability of smart mobile devices and the capability of NGN_CN, a service convergence architecture is proposed to enhance future PSTN services. Some prototype services have been implemented. This architecture can be applied to let CT domain services of NGN_CN to trigger IT domain service of Internet/Cloud more efficiently, and can potentially improve user experiences in PSTN.

PSTN transformation is arguably an integral part of NGN engineering for many telecom operators worldwide. However there is little open discussion in the literature as to how this issue was actually considered and implemented from the perspective of the telecom operators. It is expected that this paper provides some pragmatic information and can be of value for further exploration.

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