Abstract
The migration from circuit-switched to packet-based networks brings with it many new possibilities. It will allow for better usage and management of bandwidth, and will enable a variety of new applications. However, it also brings with it many challenges. Deployment of packet-based voice networks will be slow until they offer the same quality of service (QoS) and features as the existing public switched telephone network (PSTN). Emerging technologies, such as MPLS, will help address some QoS issues, but there is more to the PSTN than just voice. Operators will also have to figure out how to maintain the same QoS in the new networks for dial-up modem calls. Modems are much more sensitive to delays and jitter than voice, and as such, present a problem and will fall back to slower rates or even disconnect when encountering network conditions that do not adversely affect voice calls. As with Voice over IP (VoIP) and Fax over IP (FoIP), there is much effort going into the creation of standards to address these challenges. An emerging Modem-over-IP (MoIP) standard will ensure robust modem services over packet-based networks.

This paper discusses the issues related to MoIP, and introduces the technologies involved in creating the standard.

Introduction
Packet Telephony networks that are able to collapse voice, data and other services onto a single network offer compelling benefits for infrastructure efficiency and innovative integrated services for telecommunication service providers. Despite these benefits, with over $350 Billion invested in the installed voice network (PSTN), the shift from the PSTN to packet telephony networks will be a gradual one, with much of the existing access equipment remaining in place for the foreseeable future. This being the case, service providers will have to continue to support legacy services, such as dial-up modems for increasingly popular applications like Internet access, into the next decade and beyond.

The migration to the packet telephony network will occur as traditional switches (Class 4 or Class 5) are replaced or augmented by media gateways. Media gateways will be required to support legacy end-to-end services such as Voice, Fax and Data (Modem). Standards to address voice and fax over packet networks have been introduced over the past several years (RTP/RTCP for Voice, T.38 for Fax). Standards to address Voice-Band Modems (VBM) over packet networks (referred to as MoIP) are being defined now.

The approach to carrying modem traffic over packet networks up until now involves establishing a transparent VoIP G.711 channel that carries the raw modem samples over the network between two Media Gateways. The voice-related Echo-Canceller (ECAN), Voice Activity Detector (VAD) and Comfort Noise Generation (CNG) mechanisms are disabled. However, any change in packet delay, packet loss, or jitter behavior will cause a modem to retrain, or disconnect. In regular voice-enabled (managed) IP networks, where QoS conditions of 1% packet loss are common, modem throughput is expected to be very low when modern modem protocols (such as V.34, V.90 and V.92) are used. Again, the reason being that modems do not tolerate delay and jitter, and fall back to slower rates.

Because packet networks have to offer parity, at a minimum, to the PSTN, alternative approaches to handling MoIP are needed. With help from Surf Communication Solutions (Surf), the ITU, TIA and IETF have initiated the standardization effort needed...
to provide a better solution to the problem. While the standard is not yet finalized, it is clear that the adopted solution will involve partial termination of the modem and a reliable transport protocol.

Network Model

In a conventional setting, a client VBM is connected to the PSTN via twisted pair copper wiring, while a server modem is connected to the PSTN via a digital trunk such as a DS1 or ISDN PRI. In this setting, a modem call takes one of the following call types:

- Client modem versus server modem
- Client modem versus client modem
- Server modem versus server modem

The first type might support up to V.92 standard connection speeds (up to 56Kbps downstream and 48Kbps upstream), while the second type supports up to V.34 standard connection speeds (up to 33.6Kbps in both directions). The third type supports up to V.91 standard connection speeds (up to 56Kbps in both directions). In a conventional setting, after call establishment, a PCM-switched channel is provided between the call modem and the answer modem. Though a portion of this path might be replaced with an analog twisted pair (a tandem link), it is still treated as a conventional PSTN system.

In a hybrid setting (see Figure 1), in which a portion of the PSTN/ISDN cloud is replaced by an IP network, gateways are placed at the transition between the PSTN and the IP network. In addition, Media Gateway (GW) Controllers (MGC) are placed in the IP cloud to handle the IP signaling operations, such as call-establishment, call-control and call-termination, using IP signaling protocols, such as H.323, MGCP and MEGACO. To support near toll-quality voice service, the IP transmission path should have reasonably low delay (latency of less than 150ms), low packet loss (in the range of 1-10%) and low packet jitter parameters (less than 100ms). This hybrid IP/PSTN network is designed so that the above VBM call types may be conducted as well as regular voice and fax calls.

![Figure 1: Trunking GW Configuration](image)

Although this paper concentrates on the Media GW setting, other settings in which voice-band calls (and modem calls) are to be supported over hybrid switched and packet networks exist. Among them are residential GW devices such as Integrated Access Devices (IADs) for ADSL, cable, and other broadband connections.

Standardization Work

The MoIP-related standardization work, initiated in mid-2000 by Surf, is currently spread over several standardization bodies. Each deals with some aspects of the forthcoming standard.

- ITU SG16 Q11 and TIA TR 30.1 - deal with the actual MoIP session. This includes the physical layer (modulation, data-compression and error-correction), V.MoIP protocol messages and other system level issues.
- ITU SG16 Q2 - deals with the inter-working of
V.MoIP and the IP signaling protocol, starting with H.323.

- IETF - development of the reliable transport layer to be used by V.MoIP.

V.MoIP

Although the standard is not yet finalized, it appears that the V.MoIP standard will include partial termination of the modem and a “light-weight” reliable transport protocol to carry the data across the IP network. It is agreed (by SG16/11 and TR 30.1) that the selected MoIP types will not require any improvement in the QoS of existing voice-enabled IP networks. An additional guideline is that the emerging standard will have minimal effect on existing call-establishment and GW control protocols.

The relevant MoIP-type layer models are illustrated in Figure 2. In this paper, the only MoIP types considered are those with CPU consumption equal, or less than the consumption of a typical full modem termination implementation:

- MoIP type 0 - is handled within the scope of the VoIP channel with G.711 payload carried over an RTP/UDP transport. This is agreed to be mandatory.

- MoIP type 2a - includes local termination of Data-Pump (DP) and Error-Correction (EC) layer. The Data-Compression (DC) layer is terminated by the end modems. A reliable transport protocol is used to relay the compressed data between the two GWs. Two 2a-type flavors are being considered:
  - Fixed DC Parameters Exchanged (FPE) - in this case, the DC parameters are predetermined by the two GWs in the beginning of the MoIP session (for example, V.42bis with 1KB dictionaries). This way, the modem negotiations over the two PSTN segments are performed independently. The downside is that legacy modems with MNP 5 compression are not supported. In addition, when both end modems are V.44-enabled, the connection will use V.42bis and the advanced features of the V.44 will not be exploited.
  - Dynamic DC Parameters Exchange (DPE) - in this case, spoofing techniques (similar to techniques used with T.38 fax relay) between the two Modem-sessions are used to negotiate the DC-layer parameters between the two GWs. This means that both MNP legacy modems and the Modern V.44 features are supported. The downside is that interoperability problems could arise, especially over IP networks with long delays.

- MoIP type 3b - includes full modem termination in the GW. Reliable transport protocol is used to convey the uncompressed data between the two GWs.

- MoIP type 4 - includes local termination of the DP and EC layers. The DC layer of each Modem session is split in a way that the encoding and decoding parts are implemented on the local and remote GWs respectively.

Figure 2: Potential MoIP Types
In addition, the standard deals with call discrimination issues and call-setting parameters. For example:

- Supported DP list
- Forced modulation mode – same modulation over both PSTN segments
- Forced event transparency – various retrain events that are detected on one PSTN segment are to be initiated by the GW on the other PSTN segment
- Forced data rate – same data rate over the two PSTN segments

Service providers should find these features desirable as they enable them to monitor the integrity of the call and monitor overall session performance.

Table 1 provides a comparison between the potential MoIP types in terms of resources, robustness to IP impairments, complexity and level of difficulty in interoperability.

It shows the merits of MoIP Type 2a: it behaves well when faced with IP impairments, and it consumes only moderate CPU and memory resources. In addition, the bandwidth consumed over IP is minimized (the data is compressed). MoIP type 2a provides a well-built solution for handling Modem traffic within high-density Trunking GW systems. Furthermore, using the DPE approach, all legacy MNP 5 modems are supported and advanced compression protocols (V.44) features can be taken advantage of.

### Reliable Transport Protocol

All MoIP types, with the exception of MoIP type 0, must operate above a reliable transport layer over the IP network. The IETF is working in coordination with TR30.1 and SG16/11 on the development of a special “light-weight” protocol to be used within V.MoIP.

Among the main requirements of this reliable transport protocols are:

- At a minimum, support two-way, point-to-point sessions
- Gracefully coexist with RTP-based Voice, and might gracefully coexist with UDP/TCP for facsimile
- Be error-correcting, non-corrupting, non-erasing, non-duplicative; and might provide error detection above and beyond that assumed to be providing by the underlying IP-based packet network
- Use error correction by retransmission
- Have low latency
- Be transmit bandwidth limiting
- Be bandwidth efficient
- Use windowed flow control
- Be “light-weight”

### Inter-Working IP Signaling Protocols

The V.MoIP control plane should inter-work with H.323, MGCP and MEGACO/H.248 IP signaling protocols. The inter-working functions should include call-establishment, negotiation of MoIP session parameters, and clear down.

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**Table 1: MoIP-Type Comparison**

<table>
<thead>
<tr>
<th>MoIP Type</th>
<th>Type 0</th>
<th>Type 2a</th>
<th>Type 3b</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness to IP impairments</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>CPU Resources</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Memory Resources</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>IP Bandwidth</td>
<td>Constant</td>
<td>Compressed</td>
<td>Uncompressed</td>
<td>Compressed</td>
</tr>
<tr>
<td>Interoperability</td>
<td>Simple</td>
<td>PPE - Simple</td>
<td>DPE - Complex</td>
<td>Complex</td>
</tr>
<tr>
<td>Implementation Complexity</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

1. The term “light-weight” is articulated in various categories, such as CPU resources, memory resources, port setting and switching time. Following this line of thought, UDP/IP may be considered a “light-weight” protocol, while TCP/IP protocol is considered to be much “heavier.”

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MoIP Session Overview

This section elaborates on the MoIP session phases.

Phase 0: Call Setup

This phase is beyond the scope of the V.MoIP and it should be handled by the IP signaling protocol. In this phase, which takes place during call-establishment, both GWs should negotiate (among other things) their MoIP related capabilities, such as the supported XoIP channels (VoIP, FoIP and MoIP types) and V.MoIP transport layer-related parameters.

Phase 1: VoIP Channel (Initial Call Discrimination)

In this phase, both GWs monitor the incoming signals for “advanced modem-like” and/or fax signals. It is essential to detect these signals within tens of milliseconds, to prevent any of the signals from being relayed through to the remote PSTN segment. When these signals are detected, the controller should switch from a VoIP channel to a MoIP channel. The initial call discrimination is beyond the scope of the MoIP channel, but is part of the VoIP channel. Legacy modems, such as Bell 103, V.21, V.23 and TDD (V.18), are to be transmitted using MoIP type 0 within the VoIP channel. In this case, it is recommended to switch the payload type to G.711, disable the ECAN and VAD/CNG mechanisms, and freeze the jitter-buffer (JB) to some large value to minimize the likelihood of packet loss due to a limited buffer size.

Phase 2: Secondary Call Discrimination

In this phase, the GWs negotiate with the end modems as part of the MoIP session. The negotiation might involve V.8 or V.32bis Annex A auto-mode (PN 4930) protocols. Depending on the call-setup, forced modulation mode might be applied using a spoofing mechanism over V.8, V.8bis or auto-mode. During this phase, the MoIP channel might send a message to the controller to switch back to VoIP (MoIP Type 0) if legacy modem protocols are identified during modem start-up. Alternatively, it may request a switch to a FoIP (T.38) channel if G3 Fax or V.34HD fax are identified during start-up. There are timing requirements that must be met when switching to a V.34HD FoIP channel. This phase ends when the connection is certified as a MoIP connection.

Phase 3: Modem Training

During this phase, the modem pairs Modem1/Gateway1 (M1/G1) and Modem2/Gateway2 (M2/G2) train. According to the call setup, a forced data rate mode may be applied, using a spoofing mechanism. In addition, forced modulation mode may also be applied if a fallback is detected (for example, fallback from V.90 to V.34). In case DPE mode is enabled, a spoofing mechanism is used to force semi-synchronous entry of the modem pairs M1/G1 and M2/G2 into modem data phase.

This phase ends (possibly in an asynchronous manner) when data can be exchanged between the modem pairs M1/G1 or M2/G2 and the link layer (V.42, MNP2-4) has been established.

Phase 4: DC Layer Parameters Exchange

Depending on the call-setup and the MoIP type selected, the DC parameters are negotiated between M1/G1 and M2/G2.

Phase 5: Data Relay

This is the useful operational mode of the MoIP. This phase might be interrupted by retrain or rate renegotiation events over one of the two PSTN segments, or a clear down event.
Phase 6: Retraining
In cases where forced event transparency mode, forced modulation mode, or forced data rate mode are enabled, retrain or rate renegotiation events on one of the PSTN segments are initiated symmetrically on the other PSTN segment. This phase ends when data can be exchanged between the Modem pairs M1/G1 and M2/G2 (Data relay phase).

Phase 7: Clear-Down
This phase occurs upon one of the following events:
- Loss of carrier between the Modem pairs M1/G1 or M2/G2
- Modem session termination by user request of either M1 or M2

Part of the clear-down procedure is beyond the scope of the MoIP channel and is negotiated between the GWs. However, the MoIP channel is responsible for alerting its controller when it detects a lost-carrier event or a user request for clear-down coming from its local modem. In addition, the MoIP channel should initiate a clear-down procedure towards its local modem upon request from its controller.

Coexistence of XoIP Protocols
The emerging V.MoIP standard is joining the existing FoIP (T.38) and VoIP family of standards. The existing VoIP and FoIP standards were developed independently of each other, and they have little in common. For example, each uses a different transport protocol (VoIP - RTP/UDP, FoIP - UDP/TL). The emergence of V.MoIP could create the need for a universal XoIP approach: in terms of, for example, GW capability exchange during call-establishment, fast on-the-fly switching between different XoIP channels, and a unified transport layer.

With this in mind, the ITU and TIA are considering the use RTP/UDP as part of the transport protocol for FoIP and MoIP. In this approach, the different XoIP channels will be identified as different RTP payload types, enabling fast, on-the-fly XoIP channel switching to be supported without the need to use the current, slower, UDP port switching mechanism.

Solution
It is clear that V.MoIP will be an important feature in today’s Gateways. Each MoIP type, used over IP networks with reasonable QoS, involves partial modem termination. If MoIP is to be the robust complement to VoIP and FoIP as it is intended to be, it will need to be based on proven modem termination technology. Surf Communication Solutions has been shipping carrier-class modems for over 5 years, and uses this proven modem technology as the basis for its proprietary MoIP solution. The MoIP channel rounds out Surf’s universal port, combining VoIP, FoIP, and MoIP channels under the flexible framework of Surf’s SMP software product, a multi-channel, multi-protocol access pool.

In addition, Surf provides reference designs that roll all of this into a complete subsystem solution. This reference design includes all of the VoIP, FoIP, and MoIP protocols, the SMP Scheduler and Framework, an abstraction layer for DSP Management called SMP Engine™, and a PMC card (SurfRider™) with multiple high performance DSPs managed by an Aggregator. The hardware includes network interfaces for IP and ATM and TDM.

The flexibility of the SMP™ SW package, along with Surf’s ongoing commitment to provide state-of-the-art products to OEMs in the communications and networking markets, ensures a smooth upgrade path to the eventual ITU V.MoIP standard, regardless of...
the type adopted. The pioneering work done by Surf in the MoIP arena and the patents it holds specific to this technology puts Surf in a unique position to help OEMs integrate emerging standards into the access equipment that will help accelerate the migration from circuit switched networks to hybrid circuit - packet networks.

Fig 3: MoIP-Enabled Gateway Transcoding Subsystem

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