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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Interworking

Tandem free operation (TFO) – IP network interworking – User plane interworking

ITU-T Recommendation Y.1454

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GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	**Y.1400–Y.1499**
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Numbering, naming and addressing	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation Y.1454

Tandem free operation (TFO) – IP network interworking – User plane interworking

Summary

This Recommendation focuses on required functions for network interworking of tandem free operation, specifically the user plane interworking mechanisms and procedures for transport. It specifies a list of requirements, interworking scenarios and interworking encapsulation formats and semantics for TFO-IP network interworking.

Source

ITU-T Recommendation Y.1454 was approved on 14 December 2006 by ITU-T Study Group 13 (2005-2008) under the ITU-T Recommendation A.8 procedure.

Keywords

Gateway, interworking, IWF, RTP, tandem free operation (TFO).

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CONTENTS

ITU-T Recommendation Y.1454

Tandem free operation (TFO) – IP network interworking – User plane interworking

1 Scope

This Recommendation focuses on required functions for network interworking of tandem free operation (TFO) [ETSI TS 123053], [ETSI TS 123153], [ETSI TR 123977] and [ETSI TS 128062] and IP, specifically the user plane interworking mechanisms and procedures for transport. In particular it specifies a list of requirements, interworking scenarios and interworking encapsulation formats and semantics for TFO-IP network interworking. Since TDM connections are inherently point-to-point, this interworking defines a single connection between two interworking functions (IWFs).

TFO-IP denotes network interworking between "TFO-over-TDM" networks and "TFO-over-IP" networks. Particularly:

- TFO/TDM interfaces without any specific transport mechanisms (like GSM A*ter* interface) below the TFO protocol; and
- interworking to TFO/IP interfaces without any mobile-specific transport mechanisms like ETSI framing protocols [ETSI TS 125415] and [ETSI TS 129415].

Use of ETSI framing protocols is excluded from consideration in this Recommendation.

The TFO-IP interworking function (IWF) is a new and specific type of in path equipment (IPE) form TFO endpoint perspective [ETSI TS 128062].

This Recommendation may not be suitable for use by recognized operating agencies due to possible degradation of network synchronization performance as compared with native TDM transport.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.711] ITU-T Recommendation G.711 (1988), *Pulse code modulation (PCM) of voice frequencies.*

[ITU-T G.799.1] ITU-T Recommendation G.799.1/Y.1451.1 (2004), *Functionality and interface specifications for GSTN transport network equipment for interconnecting GSTN and IP networks.*

[ITU-T G.809] ITU-T Recommendation G.809 (2003), *Functional architecture of connectionless layer networks.*

[ITU-T H.248.1] ITU-T Recommendation H.248.1 (2005), *Gateway control protocol: Version 3.*

[ITU-T Y.1413] ITU-T Recommendation Y.1413 (2004), *TDM-MPLS network interworking – User plane interworking.*

[IETF RFC 3261] IETF RFC 3261 (2002), *SIP: Session Initiation Protocol*.

[IETF RFC 3550] IETF RFC 3550 (2003), *RTP: A Transport Protocol for Real-Time Applications.*

[IETF RFC 3551] IETF RFC 3551 (2003), *RTP Profile for Audio and Video Conferences with Minimal Control.*

[IETF RFC 4040] IETF RFC 4040 (2005), *RTP Payload Format for a 64 kbit/s Transparent Call.*

[IETF RFC 4566] IETF RFC 4566 (2006), *SDP: Session Description Protocol.*

[ETSI TR 123977] ETSI TR 123.977 V6.1.0 (2005), *Universal Mobile Telecommunications System (UMTS); Bandwidth And Resource Savings (BARS) and speech enhancements for Circuit-Switched (CS) networks.*

[ETSI TS 122053] ETSI TS 122.053 V6.0.0 (2004), *Digital cellular telecommunications system (Phase 2+)*; *Universal Mobile Telecommunications System (UMTS)*; *Tandem Free Operation (TFO); Service description.*

[ETSI TS 123053] ETSI TS 123.053 V6.0.0 (2004), *Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS)*; *Tandem Free Operation (TFO); Service description.*

[ETSI TS 123153] ETSI TS 123.153 V6.3.0 (2005), *Universal Mobile Telecommunications System (UMTS); Out-of-band transcoder control; Stage 2.*

[ETSI TS 125415] ETSI TS 125.415 V7.3.0 (2006), *Universal Mobile Telecommunications System (UMTS); UTRAN Iu interface user plane protocols.*

[ETSI TS 128062] ETSI TS 128.062 V6.3.0 (2006), *Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS)*; *Inband Tandem Free Operation (TFO) of speech codecs; Service description.*

[ETSI TS 129415] ETSI TS 129.415 V6.1.0 (2006), *Universal Mobile Telecommunications Systems (UMTS)*; *Core network Nb interface user plane protocols.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 egress IWF: See [ITU-T Y.1413].

3.1.2 ingress IWF: See [ITU-T Y.1413].

3.1.3 TFO frame [ETSI TS 128062]: A speech frame exchanged between transcoders when tandem free operation is active.

3.1.4 tandem free operation [ETSI TS 128062]: A call configuration where no transcoder device is physically present and hence no control or conversion or other functions associated with it are activated.

3.1.5 TFO speech frame [ETSI TS 128062]: A speech frame exchanged between transcoders when tandem free operation is active.

3.1.6 transcoder [ETSI TS 128062]: A device that converts the encoding of information from one particular scheme to a different one.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 TFO message: A TFO protocol signalling message which is exchanged between two participating codecs used to provide TFO.

3.2.2 TFOoIP (TFO-over-IP): This term is used to refer to the transport of TFO signals over a voice channel of an IP packet network with the encoding appropriate for TFO signals.

NOTE 1 – TFOoIP capable gateways provide the means to provide this transport.

NOTE 2 – A gateway is not responsible for the overall gateway-to-gateway performance, but may be configured to best mitigate the effects of the connected packet network impairments.

3.2.3 TFO service endpoint: The functional entity where the inband signalling (IS) and TFO protocol endpoints are located.

4 Abbreviations

This Recommendation uses the following abbreviations:

2GMS	2nd Generation Mobile System (e.g., GSM)
3GMS	3rd Generation Mobile System (e.g., UMTS)
AAL1	ATM Adaptation Layer type 1
AAL2	ATM Adaptation Layer type 2
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
BS	Base Station
BSC	Base Station Controller
CAC	Connection Admission Control
CMD	Clearmode [IETF RFC 4040]
CMD_{TFO}	TFO-aware Clearmode
GoS	Grade of Service
GSM	Global System for Mobile Communications
IPE	In Path Equipment
IS	Inband Signalling
N-ISDN	Narrowband Integrated Services Digital Network
IWF	Interworking Function
MG	Media Gateway
QoS	Quality of Service
PLC	Packet Loss Concealment
PT	Payload Type (RTP)
RN	Radio Network
RNC	Radio Network Controller
RTP	Real-time Transport Protocol
RTP/AVP	RTP Profile "AVP" [IETF RFC 3551]
SS	Silence Suppression
TDM	Time Division Multiplexing

TFO	Tandem Free Operation (also known as "Vocoder Bypass", "Codec-Bypass", or "Transcoder-Through")
TFO-IP	IWF interconnecting TFO/TDM with TFO/IP domains
TRAU	Transcoder and Rate Adaptor Unit
TrFO	Transcoder Free Operation
UMTS	Universal Mobile Telecommunications System
VBD	Voiceband Data [b-ITU-T V.152]
VBDoIP	VBD over IP
VBD_{TFO}	TFO-aware VBD mode
Vc	compressed voice mode
Vc_{fixed}	Vc mode with compressing codecs designed initially for fixed networks or wireline terminals (e.g., G.729, G.726 and G.723.1)
Vc_{mobile}	Vc mode with compressing codecs designed initially for mobile networks (e.g., GSM codecs, AMR)
VoIP	Voice over IP
Vu	uncompressed Voice mode
Vu_{SS}	uncompressed Voice with silence suppression mode
$Vu_{w/oSS}$	uncompressed Voice without silence suppression mode
Vu_{TFO}	TFO-transparent, uncompressed Voice mode

5 Conventions

This Recommendation uses traditional terminology concerning tandem free operation (TFO) in the same manner as corresponding standards defined for PLMNs such as used in ANSI or ETSI, or defined particularly for NGNs such as those in [ITU-T G.799.1].

The terms TFO frame and TFO speech frame are used in the context of clause 5 of [ETSI TS 128062] and the term TFO message is used in the context of clause 7 of [ETSI TS 128062].

6 TFO-IP interworking

There is a need for network interworking between IP domains (for VoIP NGNs) and TDM networks carrying TFO signals in 64 kbit/s TDM bearer connections in the user plane. Such an interworking function (IWF) shall be denoted as TFO-to-IP user plane IWF. Such an IWF may be provided by various network element types. The VoIP H.248 media gateway [ITU-T H.248.1] is a candidate for such an IWF type (see Figure 6-1).

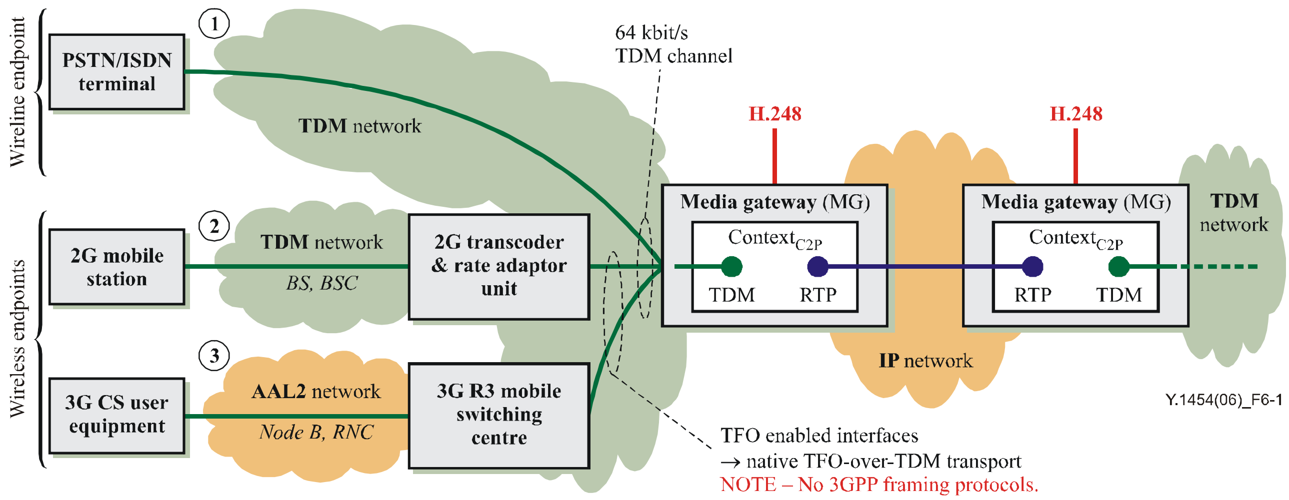

Figure 6-1 – Reference architecture (1) for TFO-IP network interworking

Figure 6-2 provides general network architecture for TFO-IP network interworking where TDM networks are interconnected through an IP network. The TDM network segments are bounded by TFO service endpoints in the scope of this Recommendation.

For the TFO-to-IP direction, the continuous TDM stream is segmented and encapsulated into RTP/UDP/IP packets by the interworking function (IWF). For the IP-to-TDM direction, the TDM segments are extracted from the RTP/UDP/IP packets and the continuous TDM stream is reassembled.

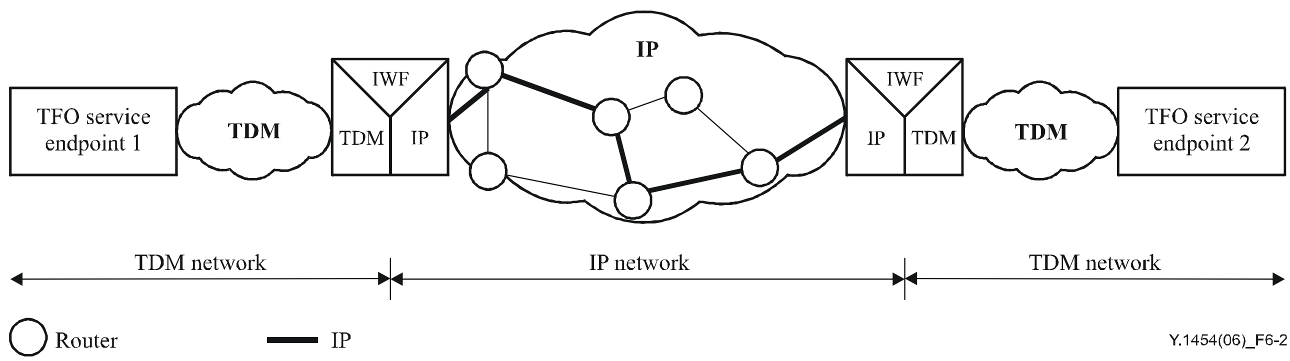

Figure 6-2 – Reference architecture (2) for TFO-IP network interworking

Figure 6-3 depicts the network functional architecture of TFO-IP interworking using the diagrammatic techniques of [ITU-T G.809].

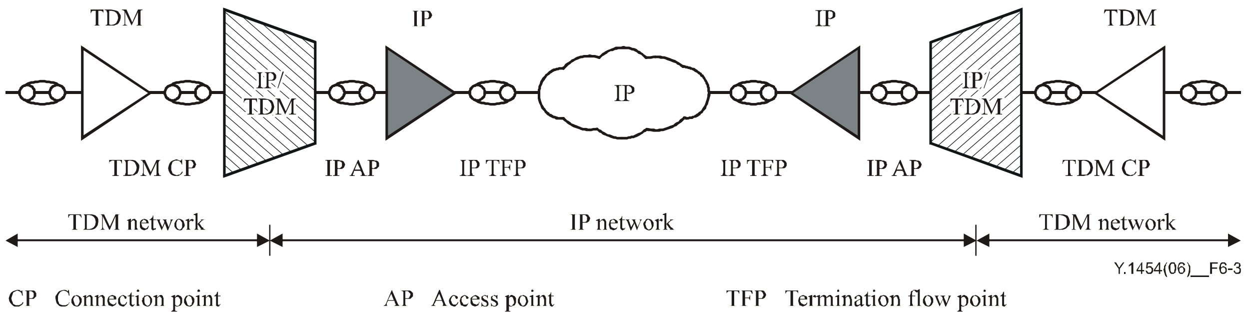

Figure 6-3 – Functional architecture of TFO-IP network interworking depicted according to the diagrammatic conventions of [ITU-T G.809]

Figure 6-4 shows the network reference model and protocol layers for TFO-IP user plane interworking.

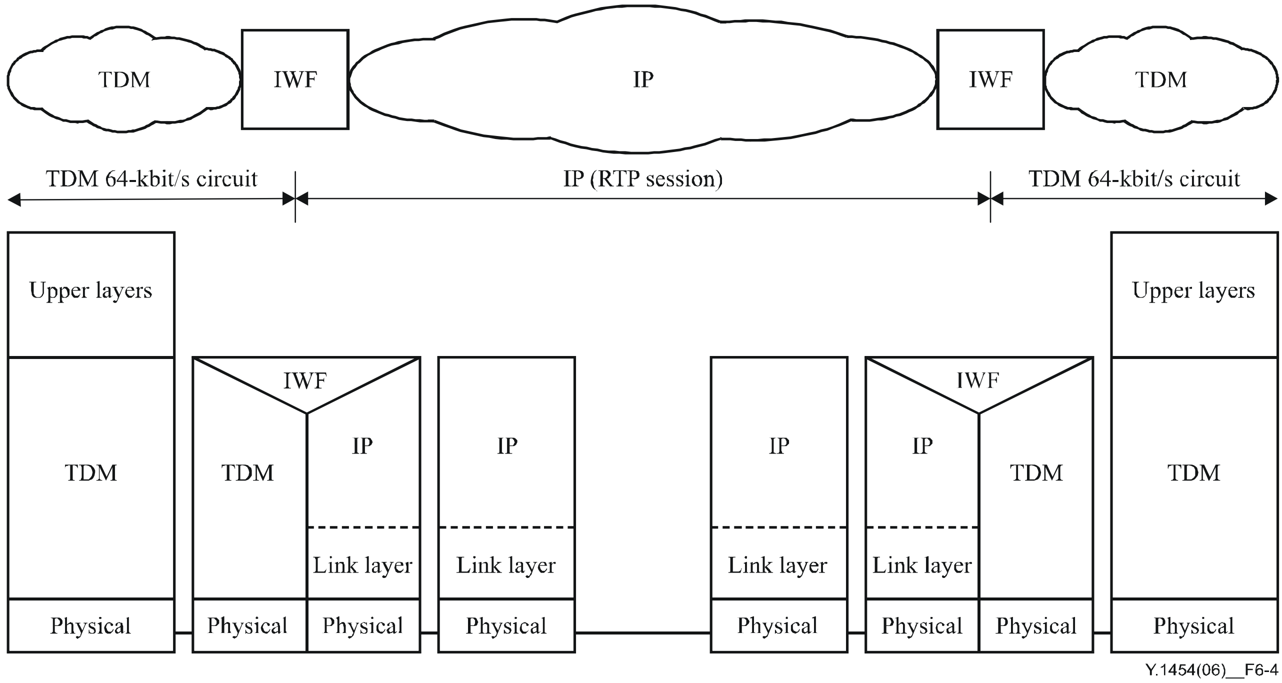

Figure 6-4 – Network reference model and protocol layers for TFO-IP user plane interworking

7 General requirements

7.1 User plane requirements

For transfer of TFO in the user plane, the following capabilities are required. User plane requirements are divided into two categories of functional and performance.

7.1.1 Functional requirements

a) In case of TFO calls, this IWF shall behave as TFO in path equipment (IPE) and shall support inband signalling (IS) mechanism defined in Annex A of [ETSI TS 128062].

b) The VoIP media gateway (MG) shall be an IPE type with a 64 kbit/s TDM termination (resulting from TDM bearer connection), and an RTP termination towards IP domain.

c) The IWF is intended for 2GMS/3GMS network architectures before 3GPP Release 4.

d) Both IWF interfaces shall not be specific to any mobile standards:

1) the TDM interface is 1×64 kbit/s;

2) the IP interface is not using any mobile-specific framing protocol.

e) The (MG) shall be able to encode G.711 voice from 64 kbit/s TDM termination to a compression (non-G.711) voice codec at RTP termination (IP domain), and decode the compressed voice to G.711 in reverse direction.

f) The MG shall be able to transport G.711-over-RTP in silence suppression (SS) mode (see Appendices I and II of [ITU-T G.711]).

g) The MG shall support "IS_Passive" mode and may support "IS_Responsive/IS_Active" mode (clauses B.2.1 and A.4 of [ETSI TS 128062]).

h) The IWF operation mode shall be "equal or better" as the applied IPE mode (Table A.2.3-1 of [ETSI TS 128062]).

i) The MG shall support TDM interfaces to fixed networks, and to mobile networks.

j) Digital transparency: Using in-band signalling implies that the link between the TFO service endpoints is transparent in the sense that the digital content of what is emitted by a TFO service endpoints is not modified. The VoIP MG in path equipments must be therefore configured in such a way that the information (signalling and coded speech) required for tandem free is not altered.

k) The MG should automatically attempt to use "TFO-over-IP" mode(s) of operation when all necessary conditions are met, and the feature is enabled.

l) Bandwidth efficiency (IP domain): This is not *per se* a mandatory requirement. It only has major relevance in case of scarce resources resulting from an existing transmission infrastructure.

TFO-over-IP transport may be used for bandwidth savings, but the major motivation is:

a) to ensure TFO mode between two TFO endpoints;

b) for optimum speech quality.

7.1.2 Performance requirements

Performance related requirements focusing on performance objectives of the TFO-IP IWF are:

a) The MG shall be compliant to "IPE transmission delay" (clause B.5 of [ETSI TS 128062]).

b) The MG shall be compliant to the performance framework according to [ITU-T Y.1541].

c) Mode switching: Any kind of state transitions at TFO service endpoints shall be unambiguously and as fast as possible detected.

Background: TFO endpoints may "frequently" transition between G.711 and TFO modes of operation. This implies "fast reaction times" by interim TFO-to-IP IWFs.

7.2 Control plane aspects

For transparent transfer of TFOoIP signals, the following are to be signalled or provisioned:

a) Setup and configuration of interworking connection.

b) Request for two point-to-point connections with equal bandwidth, and the association of their packet headers to create a bidirectional connection.

NOTE – These generic IWF control plane requirements are mapped on specific signalling capabilities for concrete control protocols. For instance, in case of the H.248 gateway control protocol, the TFOoIP IWF may be "embedded" in an H.248 context. The above signalling relates then to the basic signalling (e.g., H.248 media descriptor) for the two H.248 terminations used in this context.

7.2.1 Allocation of RTP payload type codepoints

Mode(s) of operation for TFO signals are RTP-based, thus requiring the assignment of a (dynamic) RTP payload type (PT) codepoint.

The framework, for the mapping between an RTP PT codepoint and an RTP application (here modes of operation according to clause 8.1.1) for the RTP/AVP profile, is given by [IETF RFC 3551]. The mapping table contains primarily a range of static assignments and a range of available codepoints for dynamic bindings. Static mappings (according to [IETF RFC 3551] for RTP/AVP) are out of scope of this Recommendation, initial scope is an RTP PT from the dynamic range.

7.2.1.1 Signalled allocation

Negotiation for the support and use of TFO mode(s) of operation as defined in this Recommendation is carried out at call establishment during the initial exchange of the call capabilities of the endpoints establishing the call. Indication of such support entails assigning RTP payload types to TFO mode of operation as well as the codecs.

The mechanisms for negotiation vary depending on the endpoint's capabilities exchange protocols used (e.g., the session description protocol [IETF RFC 4566] or ITU-T Rec. H.245; the call control protocol such as those defined in ITU-T Rec. H.323 and the session initiation protocol (SIP) defined in [IETF RFC 3261]; and/or the MG control protocols such as ITU-T Recs H.248 and J.171).

Syntax, semantics and procedures of signalled RTP payload type allocations TFO mode of operation are beyond the scope of this Recommendation.

7.2.1.2 Provisioned allocation

An explicit negotiation or signalled allocation is avoided when the TFO mode codepoint is provisioned via configuration management. The provisioning method requires bilateral agreement which may contain some constraints.

7.3 Fault management aspects

As individual voice channels do not carry defect indications, there are no fault management aspects.

7.4 Traffic management aspects

For calls initiated in voice or voiceband data mode (VoIP, VBDoIP), i.e., either with a G.711 or a non-G.711 codec, which may later transition to a TFO mode (TFOoIP), the IP network shall be capable of providing the required QoS as for their original mode. There are two cases depending on the initial codec and mode:

- Mode $Vu_{w/oSS}$:

  There are no dedicated bandwidth requirements in TFOoIP mode of operation in addition to that of the original modes.

- Modes Vu_{SS} or Vc:

  Additional bandwidth requirements in TFOoIP mode of operation may be of consideration due to the lower bandwidth required for the initial voice modes.

That is, the RTP bit rate based on RTP payload corresponds to 64 kbit/s. The final IP bit rate is based on the selected RTP packetization time, usage of optional IPv4 header fields and IP version.

7.5 Connection admission control for IWF

The connection admission control (CAC) may be based on various resource component types, e.g., 64 kbit/s TDM terminations, TFO-to-IP user plane IWFs, logical and/or physical resources related to RTP terminations.

A very simple CAC may be based on a counter for TFO-to-IP IWF resources (due to the deterministic multiplexing usage of such resource components). Sophisticated CACs may additionally take into account the specific TFO-over-IP mode of operation or statistically multiplexed resources like RTP bit rate at IP interfaces.

There is always a plethora of possibilities for CAC functions. A concrete CAC is usually a trade-off between computation complexity and target service guarantees (hard, soft) for QoS/GoS metrics, under consideration of specific system architectures ("bottleneck resources").

Any recommendation of a concrete CAC is therefore beyond the scope of this Recommendation.

8 Functional group considerations for TFO-IP network interworking

8.1 Overview

TFO-over-IP is the transport of TFO signals over a voice channel of an IP-based packet network with an encoder/decoder (codec) appropriate for such signals. This clause defines two possible modes of operation,

- mandatory: TFO-aware clearmode (CMD_{TFO}), see clause 8.1.1.2.2; and
- optional: TFO-transparent, uncompressed voice mode (Vu_{TFO}), see clause 8.1.1.3.

8.1.1 Definition of TFO-over-IP modes of operation

8.1.1.1 Background

Tandem free operation distinguishes two main modes of operation [ETSI TS 128062]: TFO mode and non-TFO mode. The TFO-IP IWF must take into account these modes, which are applied on the TDM side of the IWF. Defining modes of operation for TFO-over-IP is associated with voice-over-IP, therefore more background from a voice services perspective is given here:

Tandem free operation applies only to speech calls [ETSI TS 123053]. Tandem free operation applies only to two-party calls [ETSI TS 122053]. Where more than two parties are involved in a call, TFO may not be applicable. As a result, when a two-party TFO call is extended to multi-party, all the links shall revert to normal operation.

8.1.1.2 TFO-aware clearmode

8.1.1.2.1 Native RTP clearmode

Background: There are dedicated bearer services defined by N-ISDN for "unrestricted digital information", see ITU-T Rec. I.231.1 for monorate calls. Corresponding bearer services in B-ISDN are "circuit-mode data" in case of AAL2, see ITU-T Rec. I.366.2, or "circuit emulation service" in case of AAL1. The common denominator of all three bearer services types is a digitally transparent 1×64-kbit/s bearer connection:

- 1×64-over-TDM;
- 1×64-over-AAL2;
- 1×64-over-AAL1.

RTP clearmode is the corresponding technology for 1×64-over-RTP, often abbreviated as CMD/RTP. CMD/RTP is typically applied for the same ISDN teleservices in case of ISDN network interworking with VoIP NGNs.

CMD for VoIP corresponds to RTP clearmode as defined in [IETF RFC 4040]. A VoIP MG must guarantee a bit error rate (BER, on network element level requiring that no bit errors be generated) of zero for CMD bearer service.

TFO-over-CMD-over-IP is principally feasible in user plane, but needs an enhancement for "TFO stimuli" detection (see clause 8.1.1.2.2).

8.1.1.2.2 RTP clearmode together with TFO signal monitoring

The "TFO-aware clearmode" (CMD_{TFO}) is defined by:

- RTP encapsulation according to [IETF RFC 4040]; and a
- TFO detection process embedded in TFO-to-IP IWF.

  This is a simultaneous process running in parallel to the TFO-to-IP user plane interworking process. The TFO detection process shall monitor the PCM bit stream for the TFO "inband signalling (IS) protocol", analyse the protocol, and generate triggering points for user plane state transitions.

The "TFO-aware clearmode" shall be used for transport of TFO-over-IP information. It has to be noted that [IETF RFC 4040] is not affected and used as usual.

8.1.1.3 TFO-transparent uncompressed voice mode

8.1.1.3.1 Motivation

The "TFO-aware clearmode" (CMD_{TFO}) is digitally transparent for the complete 64 kbit/s media stream. It does therefore correspond to the "fully-transparent" type of an IPE (see Annex B.1 of [ETSI TS 128062]). The "TFO-transparent uncompressed voice mode" is not fully transparent, but partially transparent.

NOTE 1 – [ETSI TS 128062] classifies IPE types into five categories concerning transparency: fully-transparent, part-time transparent, unidirectional-transparent, semi-transparent and not-transparent. The "semi-transparent" mode is the closest one to the "partially-transparent" mode, provided by Vu_{TFO}.

NOTE 2 – Excerpt of [ETSI TS 128062] about "transparency categories", from subclause B.1:

In modern telecommunication networks most of these IPEs are digitally transparent for the complete 64 kbit/s data stream all the time after call establishment until call release. These IPEs are optimal and need no consideration here.

Some IPEs are most of the time digitally transparent, but disturb the link every now and then. Examples are:

– *switches, which interrupt the link during Handover;*

– *switches, which insert a kind of conference bridge for a short while during Handover;*

– *links, which do octet deletions or insertions (octet slips);*

– *DTMF generators, which insert DTMF tones sometimes for a short while.*

Other IPEs are digitally transparent in one direction, but not in the other. Examples are:

– *DTMF generators, which insert the DTMF tones only in one direction;*

– *Network Echo Cancellers (NECs), which let the signal pass unaltered towards the PSTN, but cancel the echo.*

Other IPEs are semi-transparent, i.e., let most or some of the bits pass, but not all. Examples are:

– *A/μ_Law converters;*

– *μ/A_Law converters; and*

– *especially the tandem connection of A/μ_Law and μ/A_Law converters, or vice versa.*

– *links, which insert inband signalling by bit stealing (T1 links).*

Other IPEs are not transparent at all to the digital bit stream, although the speech signal pass more or less unaltered.

EXAMPLE 1: level shifters, which adjust the signal levels, e.g., between national networks.

EXAMPLE 2: DCMEs (Digital Circuit Multiplication Equipment), which compress the bit stream by encoding/decoding the speech signal for cost efficient transmission.

Many of these IPEs – for some time – will not be compliant with the IS Message principle described in Annex A. The IS Messages will not pass these non-compliant IPEs or not in both directions, or not always. Care must be taken to identify situations where IPEs are part-time-transparent or semi-transparent, when applying IS Messages. Other IPEs – at some point in time in the future – will be compliant to the IS Message principle. The rules they have to fulfil are described below.

8.1.1.3.2 Definition

The "TFO-transparent, uncompressed voice mode" (Vu_{TFO}) is using G.711 (PCM64) encoding on RTP side. The TFO-IP IWF must ensure partial transparency for specific bits of the 8-bit samples. These bits shall not be altered between TDM and RTP side.

Which bits are affected depends on the selected IPE_Mode by the TFO service endpoints. There are 16 different modes of operations (see Table A.2.3-1 of [ETSI TS 128062]), 14 of them are partially-transparent (IPE_Mode indices 1 to 7 and 9 to 15).

The TFO service endpoint (here IS_Sender) is using the so-called IS_IPE message to command all IPEs into the required mode of "bit transparency". The TFO-IP IWF must therefore monitor this IS message type in order to select the correct transparency mode.

8.1.1.3.3 Applicability

The TFO-transparent, uncompressed voice mode has inherent limitations. This mode is restricted on the networks, which do not require support of requirement e) of clause 7.1.1.

Requirement e) of clause 7.1.1 may mean for example the usage of non-wireless specific compression codecs like G.729, G.726 or G.723.1 in the IP domain. The CMD_{TFO} mode shall be used instead in this general case.

NOTE – It has to be noted that requirement e) of clause 7.1.1 is the major motivation for this Recommendation.

8.1.1.4 Differences between TFO-IP modes of operation

For a high-level comparison, see Appendix II.

8.2 Transport label

None.

8.3 Interworking label

None.

8.4 Common interworking indicators

None.

8.5 Optional timing information

Optional timing information may be carried using a standard RTP header as defined in [IETF RFC 3550]. The RTP header shall appear immediately after the UDP/IP header (see clause 9).

9 Payload formats

The TFO-IP IWF is using standardized, "native" RTP payload formats, i.e., only RTP encapsulation as defined by [IETF RFC 3551] and [IETF RFC 4040] as identified below.

- The payload format for voice modes of operation of the TFO-IP IWF is according to:
  - clauses 4.5.14 and 4.1 of [IETF RFC 3551] for uncompressed voice as used in fixed networks (codec G.711 with A-law or µ-law) with silence suppression ($Vu_{fix,withSS}$); or

– clause 4.5.14 of [IETF RFC 3551] for uncompressed voice as used in fixed networks (codec G.711 with A-law or µ-law) without silence suppression ($Vu_{fix,w/oSS}$); or

– clause 4.5.6 of [IETF RFC 3551] for compressed voice using G.729 (Vc).

• The payload format for voiceband data (VBD) mode of operation of the TFO-IP IWF is according to:

– clause 4.5.14 of [IETF RFC 3551] for VBD according to [b-ITU-T V.152] and G.711 [ITU-T G.711] as VBD codec; or

• The payload format for in TFO-aware clearmode (CMD_{TFO}) of the TFO-IP IWF is according to [IETF RFC 4040] (see also clause 8.1.1.2.2).

10 Timing aspects

TDM networks distribute timing information in order to maintain the required performance level. Since IP networks have no inherent timing distribution mechanism, other methods of timing distribution or recovery must be provided. Such methods are beyond the scope of this Recommendation.

11 Packet loss aspects

Some degree of packet loss cannot be avoided in an IP network, hence some packet integrity mechanisms shall be provided. Malformed packets and out of order packets may also be considered as lost. Retransmission is not a viable option in general with regard to the set of real-time conversational services behind the acronym VoIP (i.e., speech telephony), and so appropriate action shall be taken to compensate for packet loss.

When loss of packets is detected, the IWF shall apply packet loss concealment (PLC). The PLC mechanism in TFOoIP mode of operation may be different, and much simpler than the PLC algorithm used in voice modes.

A simple PLC, based on the insertion of filler data, shall be sufficient for basic TFOoIP mode.

NOTE – A PLC designed specifically for "voice" is not applicable for TFOoIP because of the "transparent channel characteristic" (see IPE property in [ETSI TS 128062]) and the inband TFO protocol. Regeneration of lost IS protocol elements (by the IPE) is not required.

Dedicated PLC mechanisms for VoIP and TFOoIP are beyond the scope of this Recommendation.

12 Security considerations

Security aspects have not been addressed in this Recommendation.

Appendix I

Voice-TFO transitioning state diagrams

(This appendix does not form an integral part of this Recommendation)

This appendix provides a non-exhaustive example of state transitioning diagrams. A dedicated state diagram is typically defined by the additional capabilities supported by the network entity, in which the TFO-IP IWF is embedded.

Figure I.1 illustrates a state diagram of a VoIP MG supporting uncompressed voice with and without silence suppression, compressing codec(s) of "fixed" networks and voiceband data services.

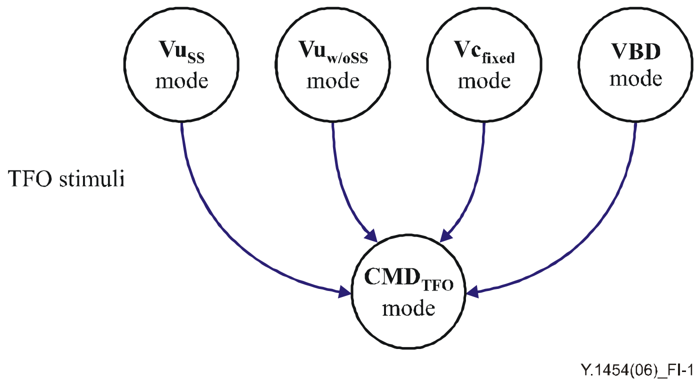

Figure I.1 – Voice-TFO transitioning state diagram (example 1)

It has to be noted that the detection of a TFO stimuli in TDM-to-IP and IP-to-TDM direction is triggering a transition into the TFO-aware clearmode state. There is no state transition in reverse direction.

Figure I.2 provides an example of a network entity supporting additionally the TFO-transparent, uncompressed voice mode.

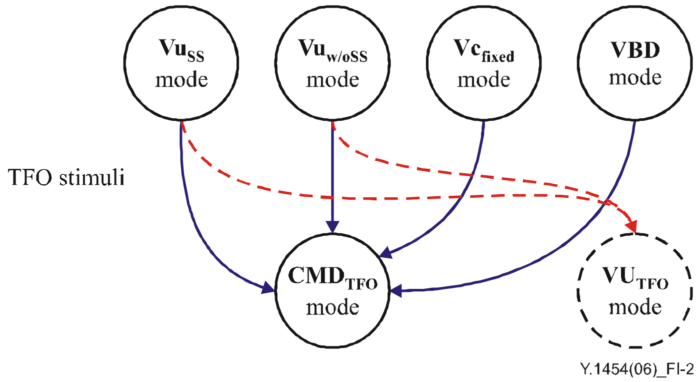

Figure I.2 – Voice-TFO transitioning state diagram (example 2)

Figure I.3 shows additional segments of the user plane connection.

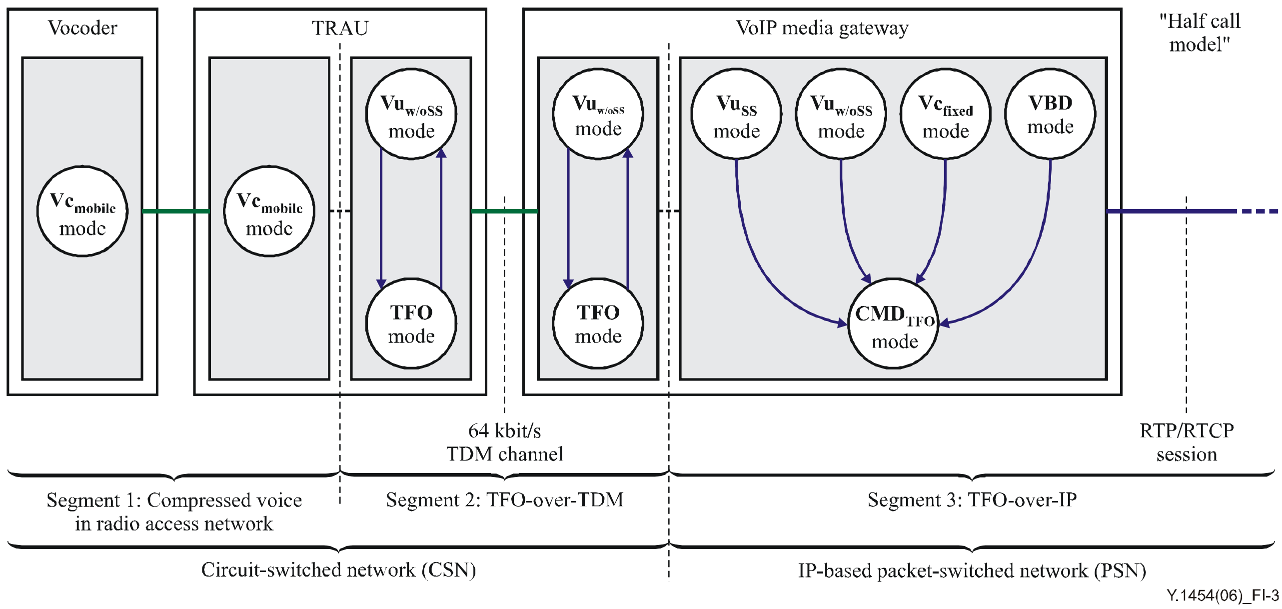

Figure I.3 – "Terminal to IP network" user plane connection

The above user plane structure may be abstracted and divided into three segments in this network scenario:

- Segment 1 with compressed voice (Vc) over a circuit-switched bearer connection (Note 1) between 2G terminals and 2G TRAUs. These bearer connections are belonging to the 2G radio access network (RAN).

  NOTE 1 – The bearer connection is of type "TDM subrate" (= 1 × 8 kbit/s, 1 × 16 kbit/s or 1 × 32 kbit/s).

- Segment 2 with TFO transport capability between 2G TRAUs and VoIP media gateways. Thus, circuit-switched bearer connections (Note 2) for TFO data in TFO mode or uncompressed voice (Vu) in non-TFO mode.

  NOTE 2 – The bearer connection is of type "TDM monorate" (= 1 × 64 kbit/s).

- Segment 3 in the IP domain, bounded here by a VoIP MG. The bearer connection is an RTP session.

There is a dual-mode *per se* on the TFO-over-TDM segment due to basic architecture of TFO.

Appendix II

Differences between TFO-IP modes of operation

(This appendix does not form an integral part of this Recommendation)

The major differences between TFOoIP modes of operation are summarized in Table II.1. It has to be noted that mode VBD_{TFO} is not defined by this Recommendation, i.e., only illustrated as complementary information.

Table II.1 – Differences between TFO-IP modes of operation

TFO-IP: Mode of operation for TFO signals:	**CMD_{TFO}**	**Vu_{TFO}**	**VBD_{TFO}** (Note 1)
Digital transparency	Full	Partial	Partial
RTP: payload type (PT) codepoint	Two PTs: one for CMD and one for initial voice mode	One PT: either '0' for G.711 µ-law (PCMU) or '8' for G.711 A-law (PCMA)	Two PTs: one for VBD (see [b-ITU-T V.152]) and one for initial voice mode
RTP: packetization times (T_p)	Same T_p as initial voice mode	Same T_p as initial G.711 mode	Same T_p as initial voice mode
TFO stimuli	TFO detector: • IS message, or • RTP PT	TFO detector: • IS message only	TFO detector: • IS message, or • RTP PT
Applicability	Generally applicable	Limited on "G.711-only" networks	Limited (Note 2)
NOTE 1 – One advantage for VBD_{TFO} mode may be the saving of one dynamic RTP PT codepoint in case of additional V.152 compliancy of the MG. The disadvantage is that the "VBD" mode must support the same partially-transparency as Vu_{TFO}. This is the main reason why CMD_{TFO} has preferences over VBD_{TFO}. NOTE 2 – The limitation is outlined in clause 8.1.1.3.2. The V.152 VBDoIP mode (with G.711 as VBD codec) would require an extension for support of the requested "transparency" by the TFO service endpoint. Such an extension would finally lead to two V.152 sub-modes: the original sub-mode for VBD signals, and the new sub-mode for TFO signals.			

Bibliography

[b-ITU-T V.152] ITU-T Recommendation V.152 (2005), *Procedures for supporting voice-band data over IP networks*.

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