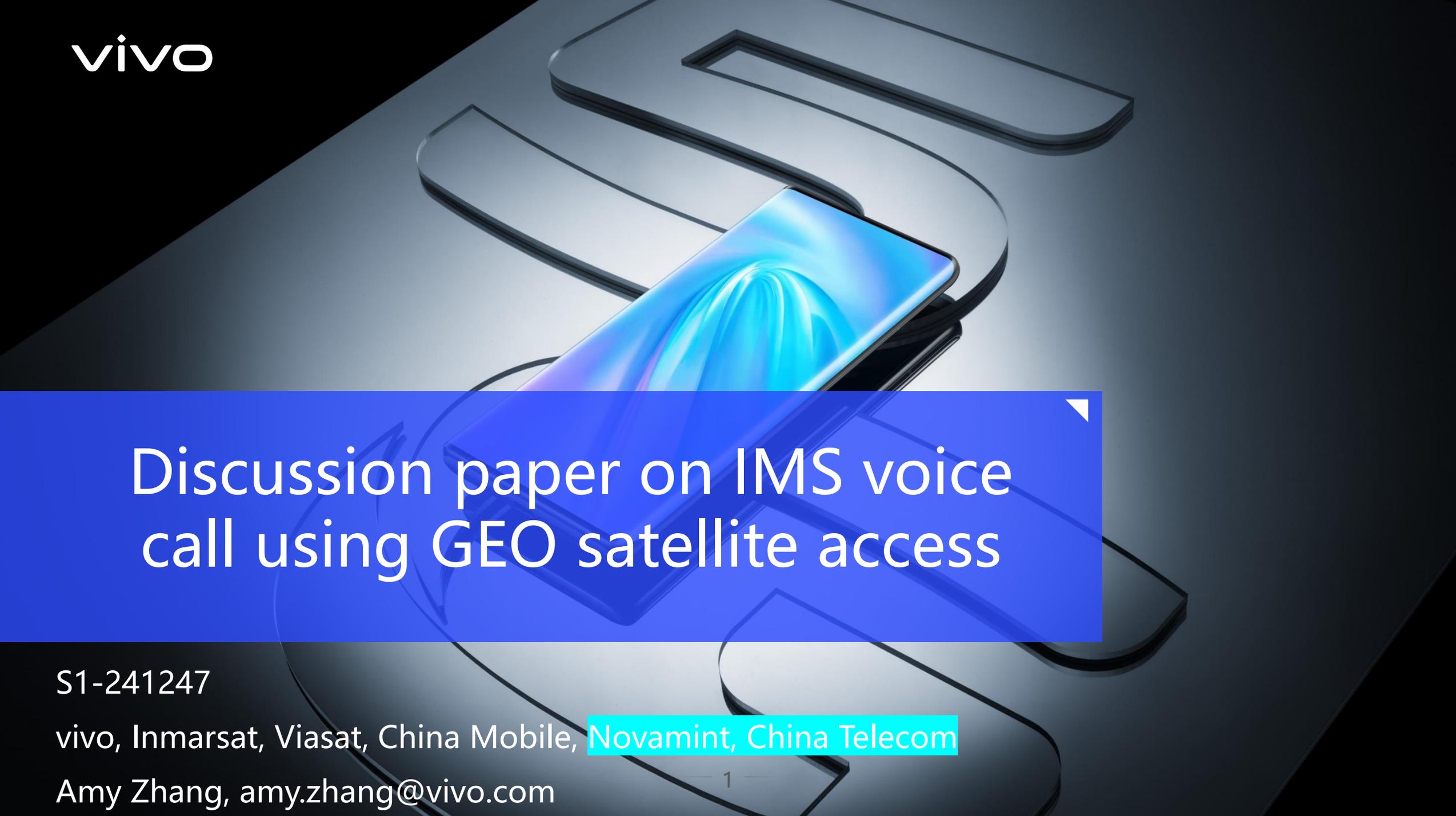




vivo



Discussion paper on IMS voice call using GEO satellite access

S1-241247

vivo, Inmarsat, Viasat, China Mobile, **Novamint, China Telecom**

Amy Zhang, amy.zhang@vivo.com

1. GEO satellite access integration in 3GPP
 2. IMS in 3GPP
 3. Key parameters for IMS voice call using GEO
 4. Key parameter – one-way transmission delay
 5. Key parameter – codec
 6. Key parameter – call setup time
 7. Conclusions
- Annex-A – Simulation design and results of GEO transmission rate

1. GEO satellite access integration in 3GPP

- IMS voice call using GEO satellite access has been proposed as one of SID objectives in SA1#105 [1]
- GEO satellite access is integrated as an access technology in 5G as specified in clause 6.46 in TS 22.261 [2].
- From the service' s perspective, all media types (voice, data, multimedia, etc) are by default supported in 5G [2].

Observation 1: a feasibility analysis regarding different access technologies to support all media types is lacking.

- Performance requirements for satellite access are introduced in clause 7.4 in TS 22.261 [2], where services like public safety, video surveillance are specified, but without distinguishing the difference between GEO and NGSO.
- GEO has limitations on high latency, limited bandwidth and resource saturation, signal attenuation, and high cost of deployment for handling data transmissions compared to NGSO, services supported by NGSO may not be supported by GEO.

Proposal 1: network performance analysis when GEO is the access technology is needed.

3GPP NTN in 5G

- Release 15: satellite access in 5G in SA1 (SI/WI); satellite scenarios and channel models in RAN (SI)
- Release 16: architecture aspects in SA2 (SI); Solutions for NR NTN in RAN (SI)
- Release 17: architecture of 5GSAT in SA2 (WI); Solutions for NR NTN in RAN (WI); IoT NTN solutions in both SA2 and RAN (WI)
- Release 18: NR NTN evolution in both SA2 and RAN (SI/WI)
- Release 19: NR NTN, IoT NTN evolution in both SA1, 2 and RAN (SI)

References:

[1]: S1-240312: "Study on satellite access - Phase 4"

[2]: TS 22.261: "Service requirements for the 5G system: Stage 1"

1. GEO satellite access integration in 3GPP – cont

- Propagation delay via satellite is investigated and specified in Table 7.4.1-1 [1], however, the other very QoS affecting aspect data rate via satellite hasn't been considered.
- Until Release 18, GEO satellite access can be integrated as the following 3 access technologies:
 - GEO supporting NB-IoT access technologies,
 - GEO supporting LTE-M access technologies,
 - GEO supporting (eRedCap) NR access technologies
- Different access technology supports different bandwidths as shown in Table 1, based on Shannon theory, data rate has a relationship with bandwidth.

Proposal 2: a simulation is proposed as a way to show the data rate aspect of network performance.

- A simulation to compare the achievable UL data rate when UL channel bandwidth is 1.4MHz (LTE-M) and 15kHz (Narrow-band) is conducted.
- The receiving device is a UE (23dBm, 0 dBi antenna gain). The detailed simulation design and results can be found in Annex-A;
- As shown in Fig.1, when the bandwidth is 1.4 MHz, the achievable UL data rate is 530.6 bps; when the bandwidth is 15 kHz, the achievable UL data rate is 942 bps;

Observation 2: the data rate cannot be improved when the bandwidth is increased because of the bad link budget of GEO (long delay, atmosphere conditions, etc)

Proposal 3: Integrating GEO as narrow-bandwidth access technology is more realistic compared to other access technologies that require more bandwidth.

Access technologies in 3GPP	Channel Bandwidth
NB-IoT	DL: 180 kHz UL: 180 kHz (multi-tone) 15 kHz (single-tone) 3.75 kHz (single-tone)
LTE (Cat.M)	DL: 1.4 MHz UL: 1.4 MHz
NR (eRedCap)	DL: 5MHz for PDSCH UL: 5MHz for PUSCH

Table. 1: Examples of supporting bandwidth with different access technologies

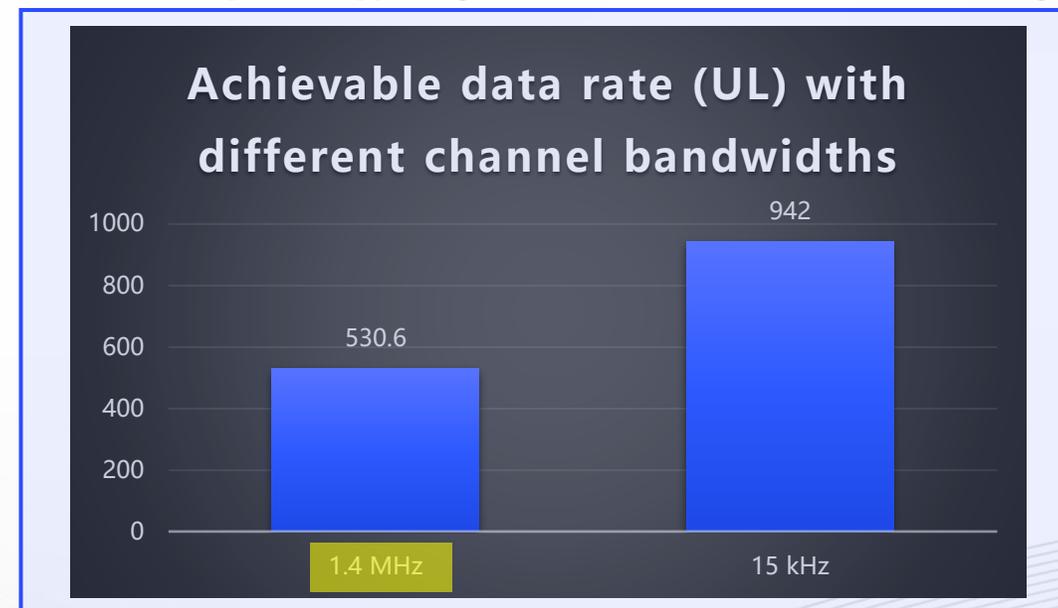


Fig. 1: Achievable data rate (UL transmission) for UE with 23dBm power class

- IMS voice call was first introduced in 3GPP's Release 5 and since then has been viewed as a basic feature in 4G and 5G [3].
- IMS has evolved in line with 3GPP's goals to improve data rates and reduce latency, to support more QoS stringent services e.g. video conference, real-time communications etc;

Observation 3.1: 3GPP hasn't revisited requirements of key parameters for IMS voice call because 3GPP improves network performance generation by generation, and the voice call-related performance requirements are by default supported by 3GPP;

- When GEO is integrated as an access technology in 5G, the achievable data rate is much lower than IMT-2020 specified [4]. As shown in Fig.1 (previous page), the UL data rate is just around **1kbps** (23dBm device, 15kHz)

Observation 3.2: The performance requirements of voice calls using GEO should be revisited, considering the limitations on network performance (especially, data rate and delay)

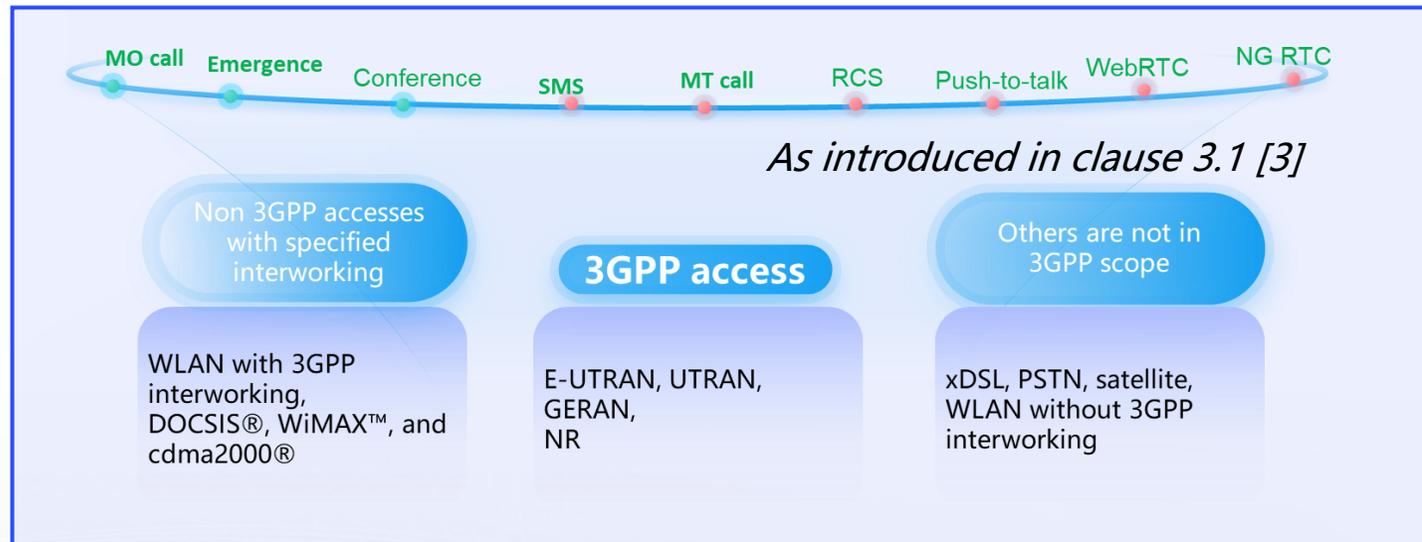


Fig. 2: IMS platform

[3]: TS 22.228: "Service requirements for the Internet Protocol (IP) Multimedia core network Subsystem (IMS); Stage 1"

[4]: ITU-R Recommendation M.2150: "Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)" .

3. Key parameters for IMS voice call using GEO

- IMS is an access-independence platform, where the aspect of performance requirements for the voice call should follow ITU Recommendations;
- **E-model** is a computational model defined by the ITU-T to assess the voice service quality from the end-user's perspective [5].
- There are 5 main factors affecting the quality of a voice call:
 - R_o : basic signal to noise ratio
 - I_s : simultaneous impairment factor
 - I_d : Delay impairment factor (delay-related, including at least transmission delay and UE delay [6])
 - I_e : Equipment impairment factor (codec bit rate-related, NOTE 1)
 - A: Advantage factor

$$E\text{-model [5]: } R = R_o - I_s - I_d - I_e + A$$

NOTE 1: **codec bitrate** refers to a bit rate used to encode/decode human voice speech for digital transmission

Observation 4: R_o : is in 3GPP scope, but depends on access technologies (stage 2 considerations); I_s and A are out of 3GPP scope, e.g. overall loudness rating depends on the speaker; I_d is affected a lot by one-way-transmission delay, which is in 3GPP scope; I_e is affected a lot by the codec bit rate, which is in 3GPP scope.

NOTE 2: **one-way transmission delay** refers to the time from when a call is initiated to when it is heard (including)

- When IMS voice call using GEO satellite access, the transmission delay is around 285ms [2], the data rate is around 1kbps (restricting codec bit rate), which significantly affects I_d and I_e .
- Apart from the speech data transmission (i.e. user plane), call set-up time is another main factor affecting people' s experience (i.e. control plane) (as defined in clause 3.1.2.1 in E.800 [6]), typically, a call setup time refers to the duration from when the call is initiated to when a ringing tone/busy tone is heard

NOTE 3: **call setup time** in IMS refers to the duration when a SIP INVITE message is sent until when a 180 ringing tone/busy tone is received [7]

Proposal 4: one-way transmission delay and codec bit rate, call setup time can be selected as key parameters to be revisited for IMS voice call using GEO.

[5]: ITU-T G.107: " The E-model: a computational model for use in transmission planning"

[6]: TS 26.131: "Terminal acoustic characteristics for telephony; Requirements"

[7]: ITU-T E.800: "Definitions of terms related to quality of service "

4. Key parameter – one-way transmission delay

- G.114 recommends that a one-way transmission delay of 400 ms should not be exceeded for general network planning to have better voice quality [8], as shown is Fig. 5, below 400ms delay can make the R score to be between 70-100, many people can satisfy;

Observation 5.1: one-way transmission delay will be bigger when using GEO satellite access and cannot satisfy the 400ms network planning requirements

Observation 5.2: one-way transmission delay can vary considering the caller' s PLMNs, scenarios of who calls who

One-way transmission delay
= UE delay + GEO transmission delay + delta

*UE delay ranges 150ms to 190ms as defined in TS23.161 [6]
GEO transmission delay is 285ms as defined in Table 7.4.1-1 in [2]
Delta is a margin value, 15ms*

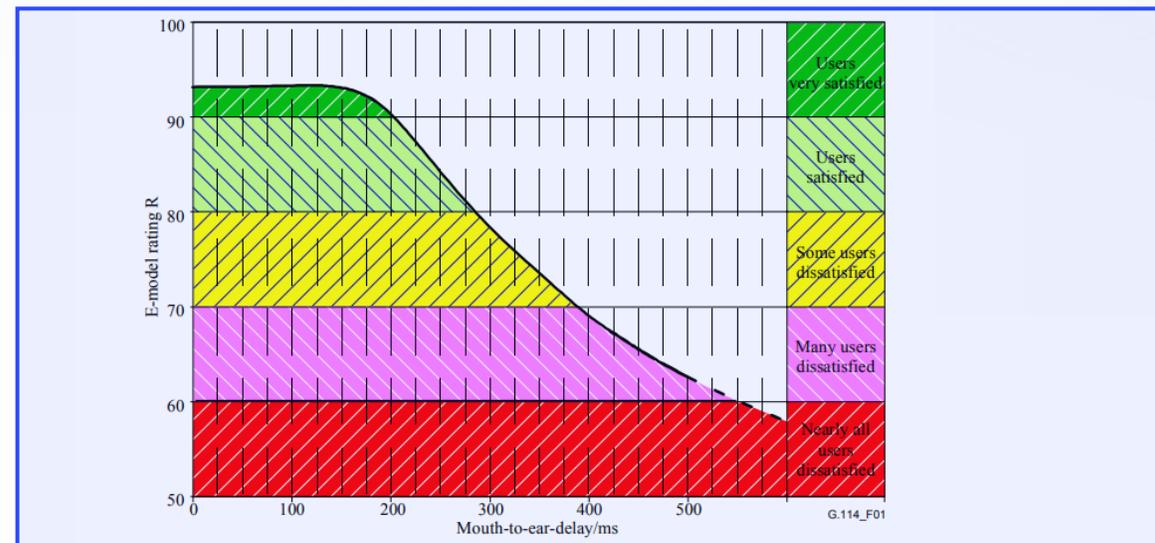


Fig. 5 One-way transmission delay v.s. R score in E-model [8]

Proposal 5: a suggested value of one-way transmission delay for an MO satellite call to terrestrial network or an MT satellite call from a terrestrial network is around **450ms-495ms**

5. Key parameter - codec

- In 3GPP, 3 kinds of codecs are supported with different bit rates:
 - AMR: 4.75 – 12.2 kbps
 - AMR-WB: 6.6 – 23.85 kbps
 - EVAS: 5.9 – 128 kbps
- As shown in Fig. 6.1, requirements on UL transmission data rate increase when codec bit rate is increased.
- UL transmission data rate is calculated as Fig. 6.2 shows, where the lowest bit rate codec-4.75kbps needs 8.8 kbps data rate, which is significantly higher than 1kbps (as shown in Annex-A)

Observation 6.1: codec has a positive correlation with UL transmission data rate, higher data rate supports high bit rate codec, and lower data rate needs lower bit rate codec.

Observation 6.2: current 3GPP GEO system cannot satisfy even the lowest codec bit rate 4.75bps.

Proposal 6: a low bit rate codec is needed for IMS voice call using GEO considering its restrictions on data rate.

Proposal 7: The suggested value for low bit rate codec is **0.4-1.2 kbps** (NOTE) considering a higher transmission data rate can be achieved by e.g. HPUE [9], protocol overhead reduction, new compression protocol etc.

NOTE: codec2 supports 0.45 kbps, 0.7 kbps, 1.2 kbps... codec bit rate for low-bandwidth required VoIP [10].

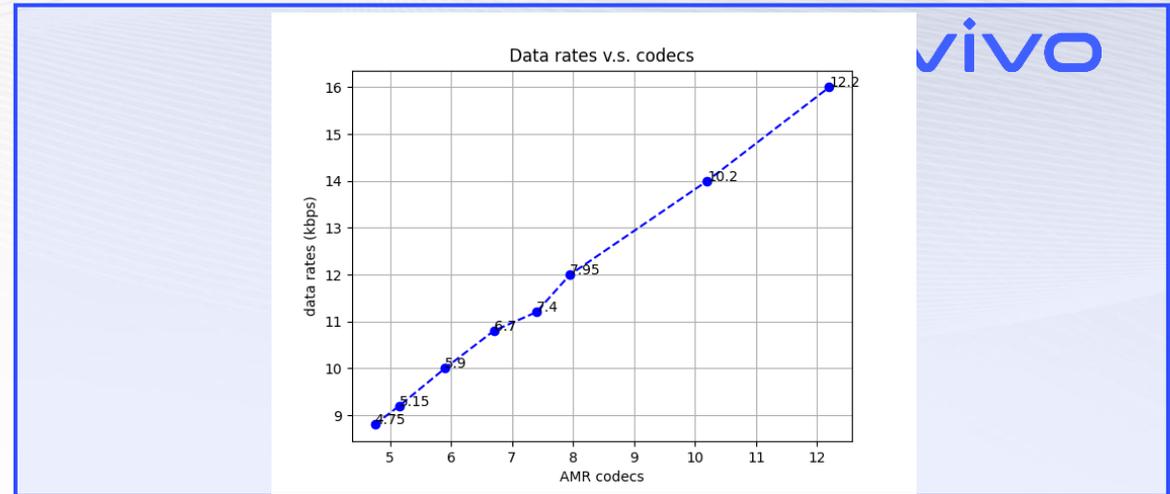


Fig. 6.1: relationship between required data rate and codecs (ptime=20ms)

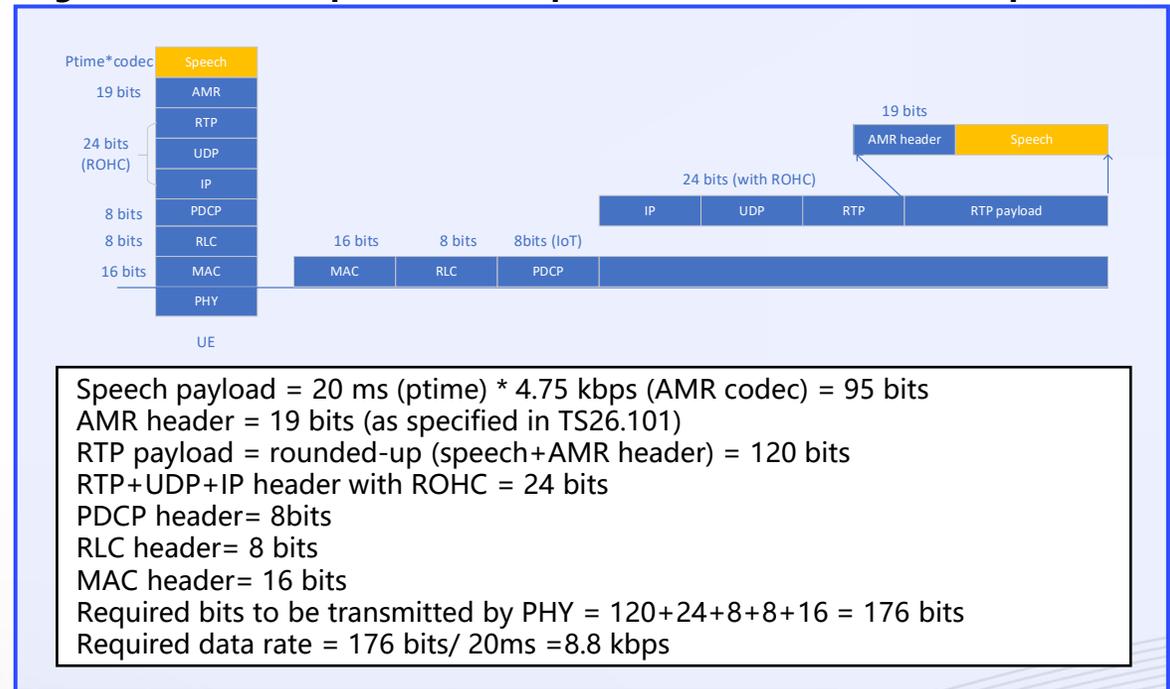


Fig. 6.2: calculation of required data rate for PHY layer transmission

[9]: RP-240857: "New WID: Enhanced requirements and test methodology for NR and IoT NTN"

[10]: https://en.wikipedia.org/wiki/Codec_2

6. Key parameters – call setup time

- The voice call setup time depends on underlying technologies:
 - 3G: 4-8 seconds (CS call)
 - 4G: 2-4 seconds (VoLTE)
 - 5G: 2-3 seconds (VoNR)
- When the call is IMS voice using GEO access, the SIP protocol will be utilized to assist the call setup. As shown in Fig. 7, a call setup time is calculated from caller sending SIP INVITE message until caller receives Ringing tone/busy tone. With a log example showing the size of a single message in IMS voice call:
 - A single SIP INVITE message takes nearly 20 seconds for transmission;
 - Call setup time (From SIP INVITE to 180 Ringing) takes nearly 88 seconds

Observation 7: IMS call setup time will be very long compared to VoLTE and VoNR when using GEO

Proposal 8: call setup time should be optimized for IMS voice call using GEO satellite access

Proposal 9: the suggested value for call setup time is 20-30 seconds [NOTE] when the caller and the callee are from the same PLMN.

NOTE: The value is calculated by considering such as IMS is simplified mechanism, HPUE [10] (higher data rate can be achieved) etc.

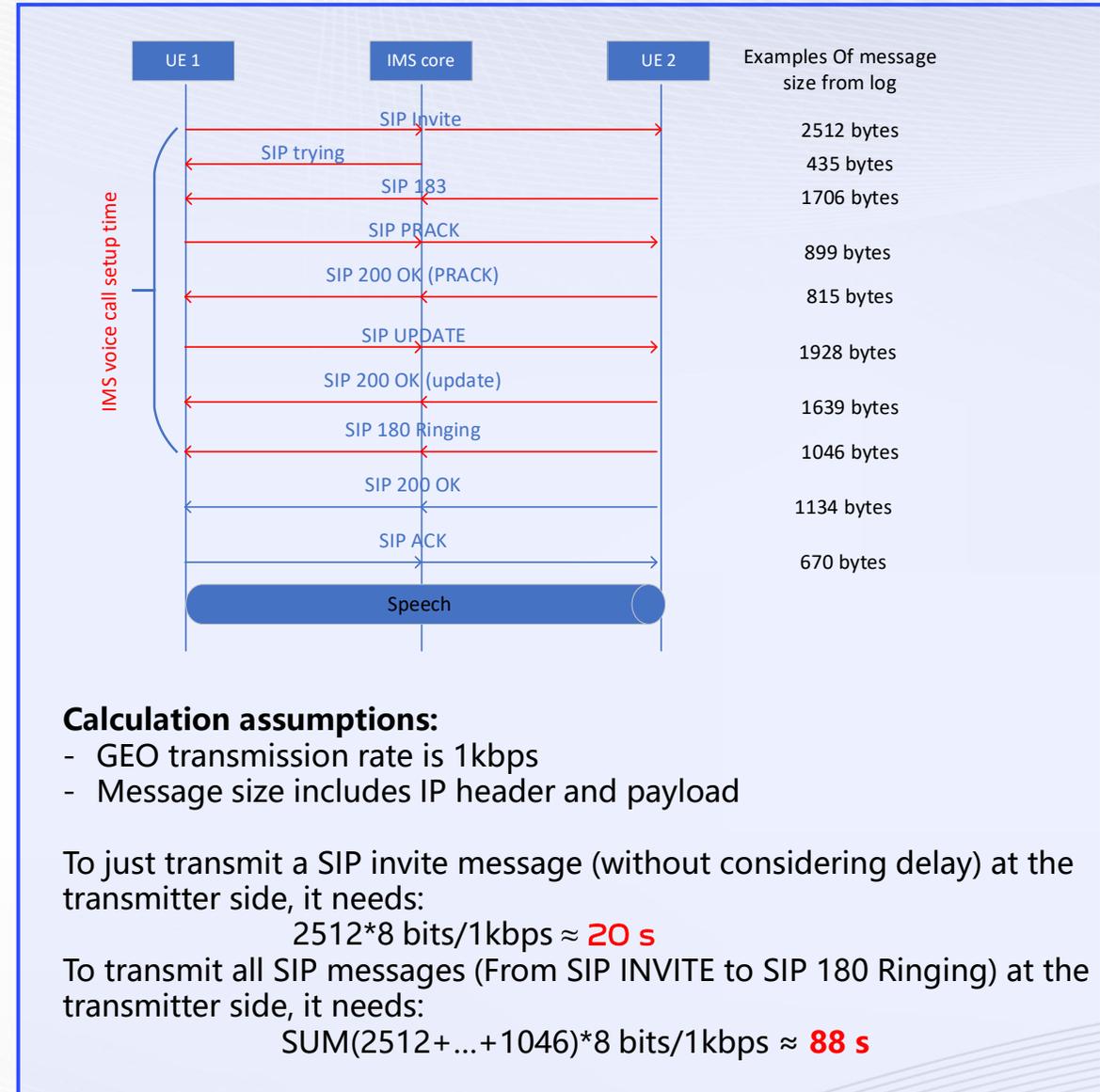


Fig. 6: Estimated call setup time calculation for IMS voice call using GEO satellite access

Based on the observations and proposals, it is suggested to capture the following requirements and KPIs for IMS voice call using GEO satellite access:

- PR-1: A 5G system shall be able to provide IMS voice call service as defined in TS 22.228 using GEO satellite access
- PR-2: The 5G system shall support IMS voice speech at bitrates (i.e. codec bit rate) lower than the transmission data rate provided by the GEO satellite access technologies.
- PR-3: The 5G system shall provide mechanisms to optimize IMS voice call setup time considering the limitations on transmission data rate offered by GEO satellite access technologies
- PR-4: The 5G system shall be able to provide IMS voice call using KPI values:
 - suggested codec bit rate: 0.4-1.2 kbps
 - suggested one-way transmission delay: 450-495 ms
 - suggested call setup time (MO to terrestrial): 20-30 s

The detailed use case can refer to **S1-241072**

vivo

Annex A: simulation parameters and design vivo

System Parameters	Carrier frequency	2GHz (S-band)	
	System bandwidth	20MHz	
	SCS	15kHz	
	Channel bandwidth	DL: 180 kHz UL: 180 kHz, 15kHz	DL: 1.4MHz UL: 1.4MHz
	Target elevation angle	20° for GEO	
Satellite Parameters	Satellite Orbit	GEO	
	Satellite altitude	35786km	
	Satellite antenna polarization	Circular polarization	
	Satellite EIRP density	45 dBW/200kHz	
	Satellite Tx max Gain	38 dBi	
	G/T	14 dB/K	
	Satellite Rx max Gain	38 dBi	
UE parameters	Antenna polarization	Linear polarization	
	Antenna configuration	1Tx, 2Rx	
	Tx transmit power	200mW (23dBm)	
	Tx antenna gain	0 dBi	
	Antenna temperature	290K	
	Noise figure	4 dB	
	Rx antenna gain	0 dBi	

Simulation design:

The design objective of this simulation is to obtain the UL transmission data rate at the UE side by considering the following constraints:

- **System parameters allowed in 3GPP specifications.**
 - A NB-IoT NTN architecture (aspects such as operating frequency band, channel bandwidth, etc) is considered;
 - modulation, redundancy version, transportation block size (TBS) and sub-frame scheduling (number of resource unit, RU) are all following 3GPP specs
- **GEO satellite link budget** that is caused by delay, atmosphere attenuation, limited UE power class, etc should be taken into consideration:
 - EIRP, antenna gain, free space propagation loss, shadow fading, scintillation fading etc are all considered to calculate the required SNR;

Required SNR [dB]

$$= \text{EIRP [dBW]} + \frac{G}{T} [\text{dB/K}] - k [\text{dB W/K/Hz}] - PL_{FS} [\text{dB}] - PL_A [\text{dB}] - PL_{SM} [\text{dB}] - PL_{SL} [\text{dB}] - PL_{AD} [\text{dB}] - B [\text{dBHz}]$$

- For channel bandwidth 1.4MHz, the required SNR = -22.38 dB
- For channel bandwidth 15 kHz, the required SNR = -2.44 dB
- **UE type is handheld, class 3 UE:**
 - Parameters for class 3 UE
 - Antenna gain in 0dBi considering UE' s capability

The simulation objective is to find the "achievable data rate" under specific channel bandwidth. The "achievable data rate" is defined as the maximum data rate attainable by using various combinations of "TBS index" and "number of RUs" that result in a block error rate (BLER) of less than 10%

- Step 1:** simulate different combinations of "TBS index" and "number of RUs";
- Step 2:** find out the combinations that satisfy 10% BLER with the calculated required SNR
- Step 3:** find out the maximum data rate with the combinations obtained in Step 2.

Annex A: simulation results

Bandwidth = 1.4 MHz

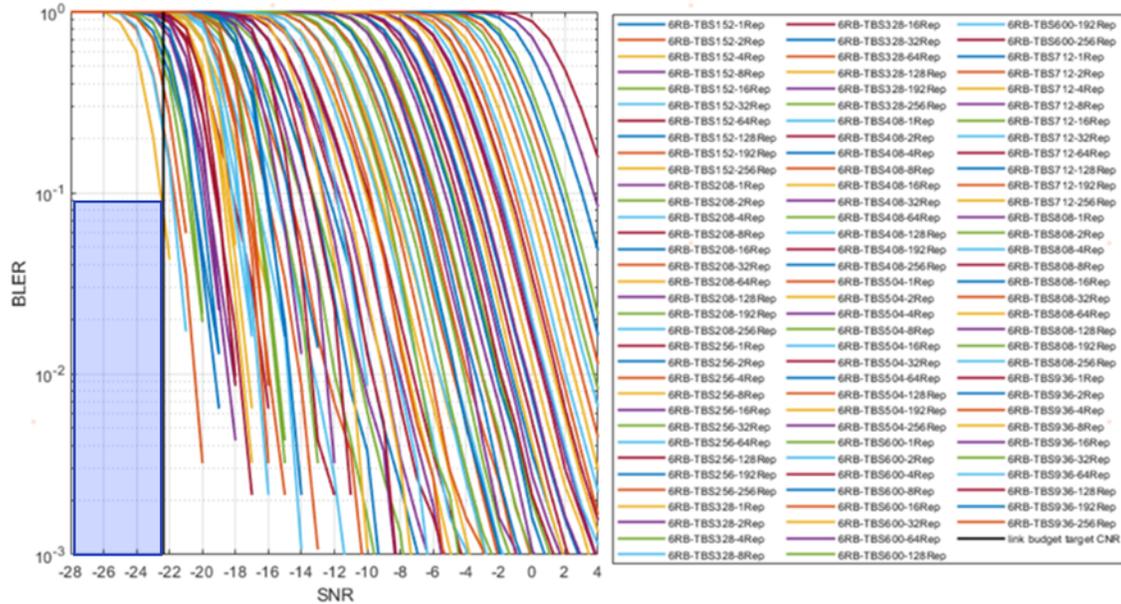


Fig 1: BLER v.s. SNR

Bandwidth = 15 KHz

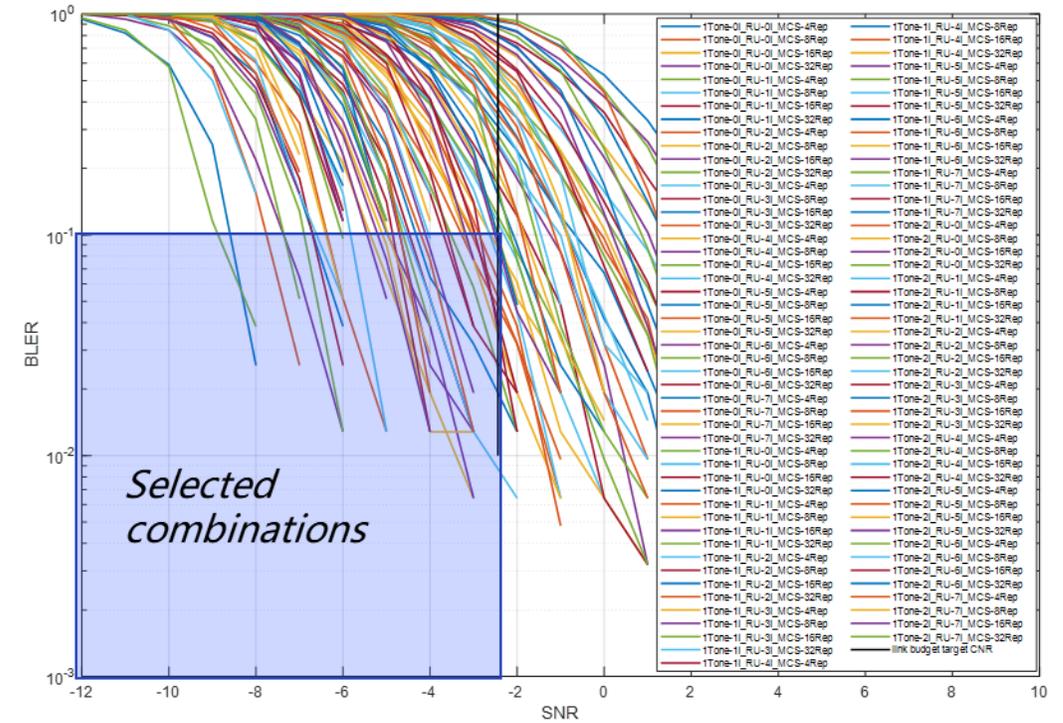
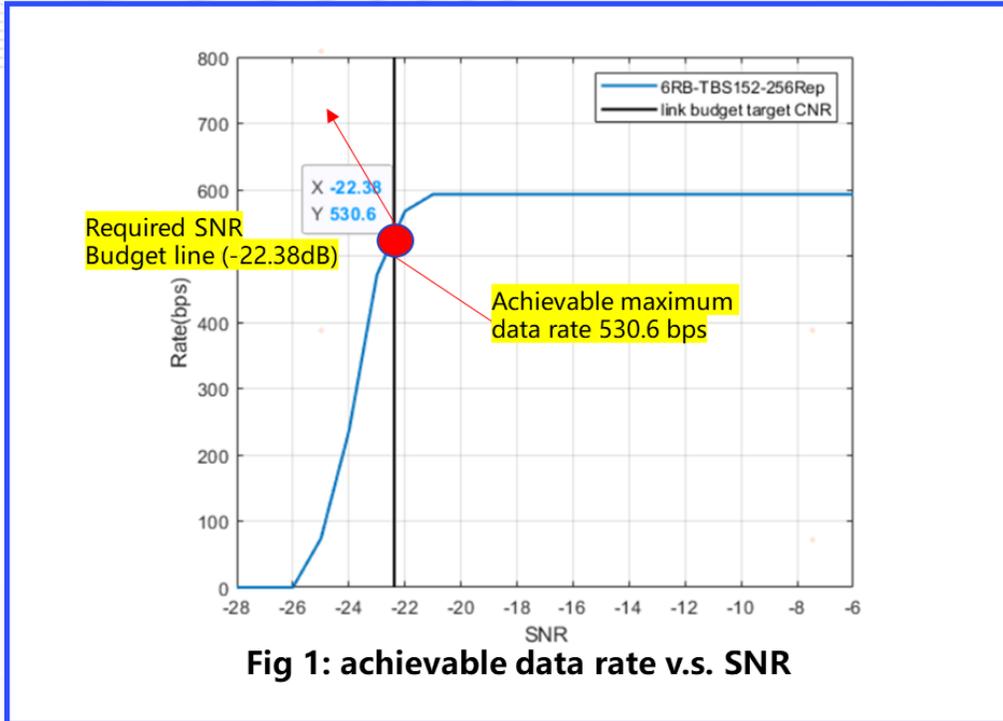


Fig 2: BLER v.s. SNR

As shown in Fig. Annex-1, the combinations of TBS index and number of RUs are selected based on the calculated required SNR and BLER 10%.

Annex A: simulation results -cont

Bandwidth = 1.4 MHz, UL transmission rate = 530.6 bps



Bandwidth = 15 KHz, UL transmission rate = 942 bps

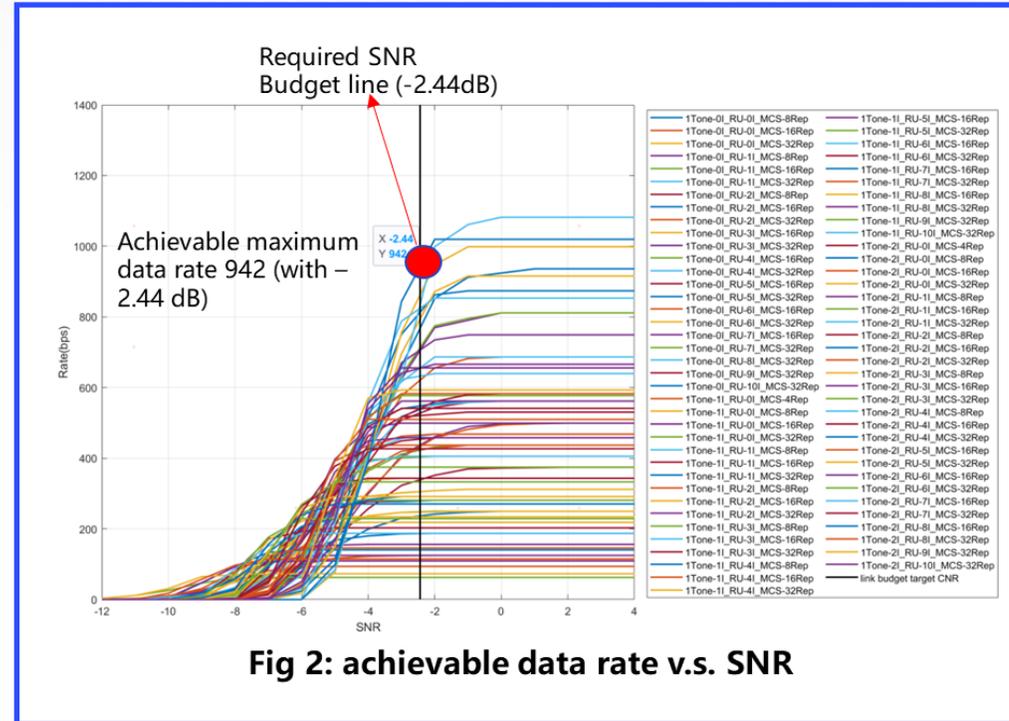


Fig. Annex-2: the achievable data rate with different combinations of TBS and number of RUs

As shown in Fig. Annex-2, it is observed that:

- Different combinations of TBS and the number of RUs contribute to different data rates, which can range significantly under specific SNR
- For a specific combination of TBS and the number of RUs, the data rate can only increase up to a certain point with SNR, after a certain point, the data rate reaches upper bound
- When channel bandwidth is 1.4MHz, the required SNR is -22.38 dB (calculated based on previous page function), the achievable maximum data rate is 129.5 bps;
- When channel bandwidth is 15 kHz, the required SNR is -2.44 dB, the achievable maximum data rate is 942 bps