

ISITEP

D61.1 - OPEN PUBLIC FUNCTIONAL SPECIFICATIONS

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Publishable extended abstract

This deliverable constitutes the open public specifications of the ISITEP Infrastructure Dimensioning Tool (IDT). The IDT is intended to support the deployment of the ISI developed solution by assisting the stakeholders' decision makers through provision of an estimation of the network elements and associated costs required for the realization of the anticipated interoperability functionalities. In particular, the tool is aimed at providing an estimation of the radio access inter-system interconnection resources (e.g., number of base stations, capacity of ISI links).

This document first describes the scope and main functions of the IDT. Afterwards, the description of its inputs and outputs together with detailed specifications of the models, computations and data templates used within the tool are addressed.

Security Release Statement (by Etienne LEZAACK - Advisory Board Coordinator)

This document is classified as PUBLIC and there are no national security sensitive issues inside it.

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1 INTRODUCTION

The development of interoperability-enabling tools, including tools for infrastructures dimensioning, training, business model assessment, and services for safety operations, is one of the four components of the ISITEP framework [1].

In this context, the design and implementation of an infrastructure dimensioning tool is addressed under Work Package 6.1 (WP6.1). The tool will support the deployment of the ISI developed solution by assisting the stakeholders' decision makers through provision of the network elements required for the realization of the anticipated interoperability functionalities.

The infrastructure dimensioning tool will receive input related to the “disaster” area (the area where common transnational operations are taking place), such as the number and the type of first responder forces that are expected to operate in the area, as well as information related to the existing infrastructures (e.g., base stations). In addition, information related to end user traffic load, available traffic resources, bandwidth requirements of ISI connections will also be taken into account.

The output of the tool will be an estimate of all affected network elements required to fulfil the communication needs within each operational scenario, providing also valuable information related to the ISI interconnection.

Furthermore, the tool will allow for the validation and verification of the designed ISI interconnection solution and their respective infrastructure and radio resources required for the specific demonstration scenarios. It may also act as a proactive tool to identify mainly capacity and radio access resources sufficiency prior to the implementation of the demonstrations.

The Infrastructure Dimensioning Tool (IDT) is composed of:

- A set of sub-tools for network dimensioning, which will provide an estimation of the required communications resources (i.e., radio access infrastructure and interconnection infrastructure).
- A logistic tool, which will provide all infrastructure equipment and related material, as well as the related cost for each simulated scenario.

The development, testing and validation of the network dimensioning sub-tools and the logistic tool will be addressed separately in a first stage. Afterwards, all these components will be integrated in a single tool.

Accordingly, WP6.1 activities are organised in 4 tasks:

- Task 6.1.1 “Open public functional specifications” (M01 - M18) is focused on defining all functional elements that will constitute the IDT. Main activities within this task are:
 - Specification of required Outputs
 - Specification of required Inputs
 - Specification of Sub-tools and their functionalities
 - Specification of Graphical User Interface
 - Definition of Open Public Specifications
- Task 6.1.2 “Network dimensioning sub-tools design and implementation” (M06 - M24) is focused on developing the network dimensioning tool. Main activities within this task are:
 - Design and tool architecture
 - Sub-tools implementation (Radio Aspects Implementation, Network Aspects Implementation)

- Graphical User Interface development
- Testing and Validation
- Task 6.1.3 “Logistic tool” (M06 - M24) is focused on developing a tool to provide all infrastructure equipment and related material, as well as the related cost for each simulated scenario. Main activities within this task are:
 - Development of a database for different manufacturers material containing cost and specific technical parameters
 - Graphical User Interface development
 - Testing and Validation
- Task 6.1.4 “Integrated Infrastructures dimensioning tool” (M25 - M30) focused on integrating all developed sub-tools into one unified IDT. Main activities within this task are:
 - Integration of all Sub-tools
 - Graphical User Interface development
 - Testing and Validation
 - Demonstration of the tool

Work conducted in the above tasks is to be reported through the following deliverables:

- D 61.1 “Open public functional specifications” (M18)
- D 61.2 “Network dimensioning sub-tool” (M30)
- D 61.3 “Logistic tool” (M30)
- D 61.4 “Infrastructures dimensioning tool” (M30)

Starting from the description of the IDT tool in the ISITEP DoW, the final orientation of the ISITEP IDT and its functionalities have been discussed and revisited as part of the Task 6.1.1 specification activities. In general terms, there is consensus on the following ideas:

- The IDT is not a Radio Planning Tool (RPT). RPTs for the design and optimisation of wireless networks, including support for PMR technologies such as TETRA and / or TETRAPOL, already exist in the market. These RPTs are able to provide very detailed performance studies of the coverage and capacity of a wireless network deployment. In contrast, the IDT is mainly conceived as a dimensioning tool, less complex than a RPT, and able to support a preliminary radio and network dimensioning process.
- The applicability of the IDT is not limited to “disaster/crisis” resource estimation but also should be applicable to routine operations (e.g., cross-border operations).
- The dimensioning of the ISI link capacity should be one of the central features.

However, there are divergent opinions on the extent to which radio related aspects should be accounted in the IDT.

On the one hand, PPDR operators involved in ISITEP project (i.e., MSB, DNK) does not see the need for the tool to handle radio capacity and coverage aspects since they already have more powerful RPTs for this purpose. In particular from Norway /Sweden perspective:

- All radio aspects are handled internally with RPTs.
- All infrastructure components are handled by PPDR operators in several configuration databases and assets.

- Regarding short-term and long-term capacity with disaster handling, short-term capacity is managed with deployable mobile bases in fixed configuration while long-term capacity is managed as part of radio planning. Therefore, there is no user case in Norway / Sweden to develop a new tool for these scenarios.

In addition, ISITEP-involved PPDR operators argue that the impact of foreign units in the radio capacity will be minimal since the approach adopted in ISITEP for network interconnection in the radio access part is based on linked talk groups that will be shared with the internal units, therefore not requiring additional resources on the radio interface.

On the other hand, the ISITEP partner (i.e., NETTECHN) with the responsibility to develop the IDT supports the view that dimensioning the radio access part is also a valuable component of the tool, which can be of high interest to end-users or even to PPDR operators just pursuing a preliminary estimation of radio access capacity and coverage without necessarily relying on the more complex RPTs.

The specifications of the IDT have been developed in close cooperation with the implementation activities being led and primarily conducted by NETTECHN in Tasks 6.1.2 and 6.1.3, which are expected to deliver the implemented sub-tools by M24.

2 DOCUMENT SCOPE

The document constitutes the open public specifications of the ISITEP Infrastructure Dimensioning Tool (IDT). The specifications are organised as follows:

- Section 4: Overview of the tool, covering its scope and main functions.
- Section 5: Description of inputs and outputs.
- Section 6: Detailed specifications of the models, computations and data templates used within the tool, together with the specification of its GUI features when relevant.

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

This section is intended to capture the definitions of some key terms used in the document for the purpose of increased consistency:

ISI over IP (also referred to as **IP ISI**): IP-based implementation of the ETSI TETRA Inter-System Interface (ISI).

TETRA ISI (also referred to as **E1 ISI**): TETRA ISI standard specified by the European Telecommunications Standard Institute (ETSI) [2]. The implementation of this standard is based on Time Division Multiplexing (TDM) interconnection (E-carrier interfaces such as E1).

Network operator: the authority or company that runs the TETRA/TETRAPOL network and who has people or organisations as customers.

Migration: act of changing to a location area in a foreign network (either with different Mobile Network Code and/or Mobile Country Code) other than the subscriber home network. Typically, visiting subscribers are pre-provisioned in the foreign network to support migration.

Roaming: utilization of a mobile terminal in a network other than the one where the mobile is subscribed but on which the mobile can still be located and operated by agreement between the respective network operators. Pre-provisioning is not strictly necessary in roaming since most parameter settings are typically retrieved from the home network through the inter-system interfaces. In this document, roaming and migration are used interchangeably.

Transport or transit services carrier: an intermediate entity that provides interconnection in different levels (Service, Transport).

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| Acronym | Definition |
|---------|-------------------------------------|
| ANF | Additional Network Feature |
| AVL | Automatic Vehicle Location |
| BS | Base Station |
| cRTP | Compressed RTP |
| DL | Downlink |
| E | Erlang |
| EC | Emergency Call |
| EIRP | Equivalent Isotropic Radiated Power |
| FM | Fade Margin |
| GC | Group Call |
| GUI | Graphical User Interface |
| IC | Individual Call |
| IDT | Infrastructure Dimensioning Tool |
| IP | Internet Protocol |
| IPsec | IP Security |
| ISI | Inter System Interface |
| L2 | Layer 2 (Link Layer) |

| | |
|-------|--------------------------------------------|
| L3 | Layer 3 (Network Layer) |
| MM | Mobility Management |
| MS | Mobile Station |
| PD | Packet Data |
| PDU | Protocol Data Unit |
| PMR | Professional/Private Mobile Radio |
| PPDR | Public Protection and Disaster Relief |
| PPS | Packets per Second |
| PS | Public Safety |
| PSTN | Public Switched Telecommunications Network |
| QoS | Quality of Service |
| RTP | Real-Time Transport Protocol |
| SDS | Short Data Service |
| SIP | Session Initiation Protocol |
| SS | Supplementary Service |
| SwMI | Switching and Management Infrastructure |
| TC | Telephone Call |
| TCP | Transmission Control Protocol |
| TETRA | TErrestrial TRunked RAdio |
| TRX | Transceiver |
| UDP | User Datagram Protocol |
| UL | Uplink |
| VAD | Voice Activity Detection |
| VoIP | Voice over IP |
| VPN | Virtual Private Network |

4 SCOPE AND FUNCTIONS

The main goal pursued through the development of the ISITEP Infrastructure Dimensioning Tool (IDT) is to create a user-friendly simulation tool for:

- Assisting engineering efforts towards wireless networks design.
- Assisting engineering efforts in preliminary radio network design calculations.
- Providing reliable input to decision makers for cost control handling.
- Being applicable for various wireless technologies (TETRA, TETRAPOL) and being easily expandable to others, if required.
- Providing in a time-efficient manner, accurate network dimensioning estimations for wireless network deployments.

The IDT will provide estimations of the following communications resources:

- Radio access infrastructure: TETRA/TETRAPOL radio access and transmission equipment needed in an intervention area where a number of PPDR forces from different networks are going to be deployed.
- Interconnection infrastructure: ISI equipment and associated external links that interconnect the TETRA/TETRAPOL networks involved in the joint or cross-border operations.

These estimations will be based on the coverage and capacity needs arisen in the intervention area (the area where common operations are taking place). Information about existing infrastructures will also be accounted so that the tool can estimate the need for additional/temporary equipment to be deployed.

The IDT comprises different functions organized into several sub-tools:

- Radio network dimensioning sub-tools:
 - Base Station (BS) dimensioning calculator: Provides reliable estimates of the number of BSs needed to fulfil both coverage and traffic requirements.
 - Traffic calculator: Performs different types of traffic calculations according to the selected technology.
 - Cell Range calculator: Calculations of BS cell range taking into account numerous BS, Mobile Station (MS) and Link parameters.
 - Link Balance calculator: Quick and reliable link balance estimations and proper selection of equipment in both BS and MS sides.
 - EIRP calculator: Equivalent Isotropically Radiated Power (EIRP) calculations for both UpLink (UL) and DownLink (DL) directions.
 - Path Loss calculator: Calculations of Path Loss as a function of various parameters (e.g., distance, MS height, BS height, etc.).
- ISI capacity dimensioning sub-tools:
 - ISI bandwidth dimensioning calculator: Provides reliable estimates of the capacity needed in the ISI links.
 - ISI traffic calculator: Performs different types of traffic calculations according to the provisioned ISI bandwidth and the considered QoS requirements (e.g., blocking probability).

- Logistic Tool:
 - Network resources inventory: Provides a detailed list and characteristics of the network equipment needed to support a given simulated scenario.
 - Network cost calculator: Provides an estimation of the cost of network resources for each simulated scenario.

An illustration of the scope of the IDT scope and main functions is depicted in Figure 1.

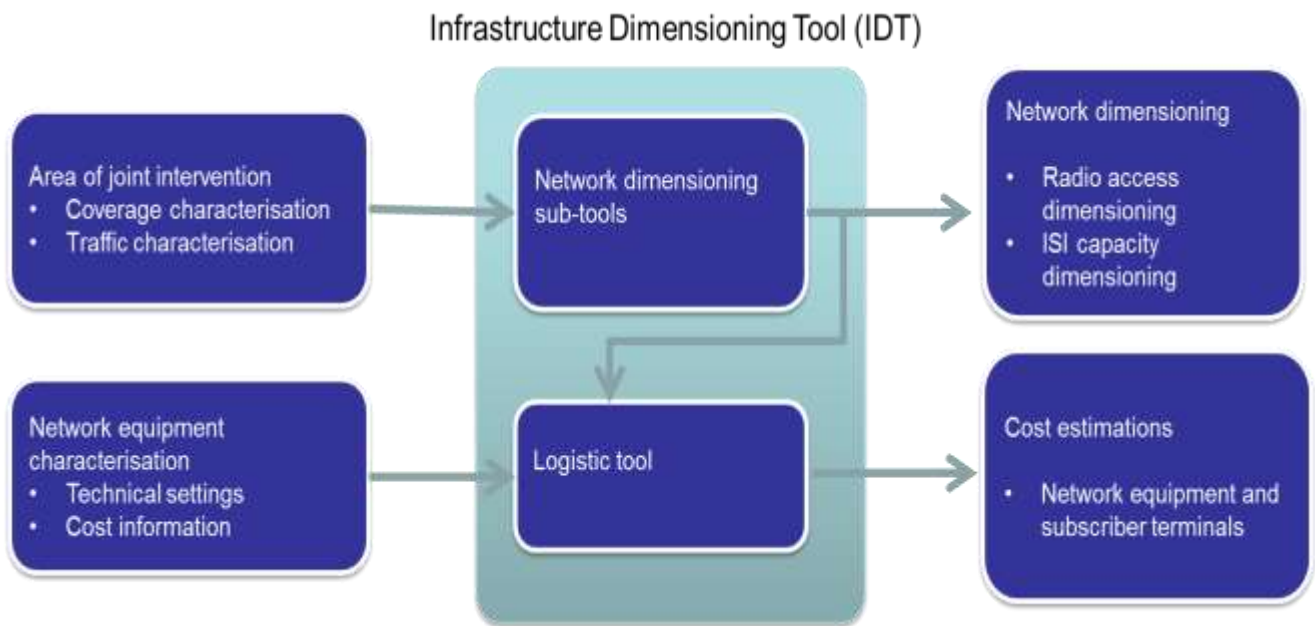


Figure 1. Illustrative view of the scope of the ISITEP Infrastructure Dimensioning Tool (IDT)

5 IDT'S OUTPUTS AND INPUTS

The IDT will provide the following outputs:

- Minimum number of BS and transceivers (TRXs) required to fulfill both coverage and traffic requirements.
- Minimum capacity of the ISI links between the networks of the different PPDR users participating in the intervention area.
- Total equipment cost estimate in order to establish each provided solution.

In addition, useful calculations used either in the preliminary or actual dimensioning phase will also be provided by the tool such as EIRP, Cell Radius and Path Loss calculations. These calculations can be performed either in a stand-alone mode or as part of the whole dimensioning procedure.

For the computation of the above outputs, the users of the tool will be able to provide input about the following settings:

- Selection of wireless access technology. The tool should be able to perform calculations for different wireless technologies such as TETRA or TETRAPOL.
- Selection of the ISI technology (e.g., TETRA ISI or IP ISI).
- Selection of the appropriate propagation model employed in the calculations. According to the pre-selected technology, as well as operation frequency and terrain characteristics, the appropriate propagation model to perform the required calculations will be defined.
- Coverage area characterisation. The coverage area should be defined from a list of geographical coordinates or by means of selecting an area on a visual map.
- Traffic characterisation. Information needed to characterise the traffic in the intervention area. This comprises number of individual users and talk groups, session generation rates and session characteristics (e.g., call duration).
- Selection of the desired quality-related inputs. Quality-related inputs are the requirements set out to provide a certain level of service. These inputs directly translate into Quality of Service (QoS) parameters such as grade of service (blocking probability or probability that connection establishment time exceeds a given threshold), throughput, latency and losses.
- Characterisation of existing infrastructures. IDT's users will be able to provide information regarding the number and characteristics of BSs existing in the intervention area. Also details of existing ISI equipment and interconnection links. This will allow the tool to show to make a differential dimensioning analysis depending on whether existing infrastructures are accounted or not in the dimensioning process.
- Network equipment characteristics from different manufacturers will be available and selectable from the database within the logistic tool. Users will be also able to customise the settings as desired to see the impact on the dimensioning results. This includes both technical settings and costs.

In addition, the following inputs will be necessary to support the internal calculations and populate the database associated with the logistic tool:

- Characteristics of network equipment and terminals from various manufacturers.
- Information regarding network equipment and terminal costs according to each manufacturer and according to operators in the neighbourhood of the case. Manufacturers' database should contain information regarding equipment cost.

- Propagation models. Suitable empirical or deterministic propagation models to be used in the dimensioning process.
- Traffic models. Traffic models for all services and applications being used in the intervention area.
- Protocol stacks for ISI interface. Details of the protocol stack solution used for signalling and data planes in the ISI interface.

6 TECHNICAL CHARACTERISTICS

Detailed specifications of models, inputs and outputs of the different functions are addressed in the following, together with the specification of its most relevant GUI features.

6.1 Parameters used within the IDT

Table 1 introduces and compiles the main parameters used in the IDT to support simulation calculations.

| Parameter abbreviation | Parameter full name | Units |
|-------------------------------|---------------------------------------------------------------------|-------|
| $EIRP_{(dBm)}^{BS}$ | Effective Isotropically Radiated Power of the BS | dBm |
| $TxPower_{(dBm)}^{BS}$ | Transmit Power of the BS | dBm |
| $Gain_{(dBi)}^{Ant(BS)}$ | Antenna Gain of the BS | dBi |
| $EIRP_{(dBm)}^{MS}$ | Effective Isotropically Radiated Power of the MS | dBm |
| $TxPower_{(dBm)}^{MS}$ | Transmit Power of the MS | dBm |
| $Gain_{(dBi)}^{Ant(MS)}$ | Antenna Gain of the MS | dBi |
| IP_R | Received Isotropic Power | dBm |
| L_p | Path Loss between a BS and a MS | dB |
| f | Operating frequency | MHz |
| h_b | BS antenna height above ground | m |
| h_m | MS height above ground | m |
| d | Distance between BS and MS | Km |
| $a(h_m)$ | Antenna correction factor | dB |
| b | Propagation model correction exponent | |
| $C_{f(OA)}$ | Propagation model correction factor for Open Area | dB |
| $C_{f(RA)}$ | Propagation model correction factor for Rural Area | dB |
| $C_{f(SA)}$ | Propagation model correction factor for Suburban Area | dB |
| $MaxAllowablePathLoss_{(DL)}$ | Maximum allowable path loss in DL | dB |
| $MaxAllowablePathLoss_{(UL)}$ | Maximum allowable path loss in UL | dB |
| $Rx_{sens(MS,static)}$ | Receiver Sensitivity for MS for static operation (MS is stationary) | dBm |
| $Rx_{sens(MS,dynamic)}$ | Receiver Sensitivity for MS for dynamic operation (MS | dBm |

| | | |
|--------------------------|---------------------------------------------------------------------|------|
| | is moving) | |
| $G_{ant(MS)}$ | Receiver Antenna Gain of MS | dBi |
| $G_{Div(MS)}$ | Receiver diversity gain for MS | dB |
| $L_{con(MS)}$ | Connector losses in MS | dB |
| $L_{Cab(MS)}$ | Cable losses in MS | dB |
| $L_{other(MS)}$ | Other losses in MS | dB |
| $Rx_{sens(BS,static)}$ | Receiver sensitivity for BS for static operation (MS is stationary) | dBm |
| $Rx_{sens(BS,dynamic)}$ | Receiver sensitivity for BS for dynamic operation (MS is moving) | |
| $G_{ant(BS)}$ | Receiver antenna gain of BS | dBi |
| $G_{Div(BS)}$ | Receiver diversity gain for BS | dB |
| $L_{con(BS)}$ | Connector losses in BS | dB |
| $L_{Cab(BS)}$ | Cable losses in BS | dB |
| $L_{other(BS)}$ | Other losses in BS | dB |
| <i>CableLength</i> | Length of cable between antennas and BS equipment | m |
| <i>CableLoss / meter</i> | Cable loss per meter | dB/m |
| <i>#connectors</i> | Number of connectors in BS | |
| <i>Loss / connector</i> | Loss per connector in BS | dB |
| F_{LU} | Link Unbalance factor | dB |
| <i>FM</i> | Fading Margin | dB |
| σ | Standard deviation for lognormal distributed slow fading | dB |
| <i>FFM</i> | Fast Fading Margin | dB |
| <i>IFM</i> | Interference margin | dB |
| L_{BP} | Building penetration Loss | dB |
| <i>A</i> | BS traffic Capacity | E |
| <i>C</i> | BS available traffic channels | |
| <i>#MCCH</i> | Number of Main Control Channels (MCCH) in a BS | |
| <i>GoS</i> | Grade of Service | |
| P_{Cell_Edge} | Coverage probability at cell edge | |
| P_B | Blocking Probability | |

| | | |
|----------------------------|----------------------------------------------------------------------------------|-----------------|
| n_t | Trunking efficiency | |
| P_Q | Queuing Probability | |
| T | Average call duration | s |
| $P_w(t)$ | Probability that a queued call waits for more than a given time t | |
| #BS | Number of BS | |
| N_{TRX} | Number of TRXs per BS | |
| CoverageArea | Coverage area requirement | km ² |
| R | Cell range | km |
| Traffic Requirements | Traffic Requirements | E |
| N_{Users} | Number of users | |
| TP_{Users} | Users traffic Profile | E |
| TL_{BS} | Traffic load per BS | E |
| $A_{v,ISI}$ | Offered voice traffic in Erlangs over the ISI link | E |
| $\lambda_{v,ISI}$ | Call arrival rate at the peak period over | Call/s |
| T_{ISI} | Average service time or hold time of voice calls over the ISI | s |
| $N_{v,ISI}$ | Maximum number of voice calls/circuits simultaneously active across the ISI link | |
| $\lambda_{d,ISI}$ | Data message rate | Message/s |
| L_{ISI} | Average message size | bit |
| $R_{d,ISI}$ | Average data bit rate of SDS/Status message services over the ISI | bit/s |
| $A_{d,ISI}$ | Average ISI link loading for data services during the peak period | E |
| \bar{D}_{ISI} | Average packet delay in the ISI link | s |
| $\text{Prob}(d > D_{ISI})$ | Probability of buffer delay d exceeding D_{ISI} seconds in the ISI link | |
| $C_{d,ISI}$ | Capacity of the ISI link between two SwMI for data services | bit/s |
| $C_{v,ISI}$ | Capacity of the ISI link between two SwMI for voice services | bit/s |
| $C_{s,ISI}$ | Capacity of the ISI link between two SwMI for signalling | bit/s |

| | | |
|-------------|-------------------------------------------------------|--|
| $N_{d,ISI}$ | Number of circuits in the ISI link for data services | |
| $N_{v,ISI}$ | Number of circuits in the ISI link for voice services | |
| $N_{s,ISI}$ | Number of circuits in the ISI link for signalling | |

Table 1. Main parameters used in the IDT to support the simulation computations

6.2 Radio access dimensioning

6.2.1 Radio propagation models and cell coverage

Radio propagation models are mathematical representations of the average loss in signal strength over distance. Due to the random nature of the radio propagation losses, fading margins are added to this average loss to account for slow and fast fading in order to have a more reliable estimation to use in the power link budget.

One of the considerations which should be taken into account is the definition of the path loss calculations in respect to the different area types. Those area types should be specified as following:

- Dense urban
- Urban
- Suburban
- Rural
- Open

The traditional propagation models such as Okumura-Hata or COST 231 should be adapted to meet the TETRA characteristics and additionally predefined tuning could be applied in order to achieve more precise simulation results. Correction factors are supported to adapt the propagation models to the different area types.

Satisfactory cell coverage at a given distance from a BS is assumed to happen when the received signal power is above the receiver sensitivity for the case of noise limited systems. An interference margin (IFM) is added to the receiver sensitivity to consider the case of an interference limited system. Different receiver sensitivities are specified for moving terminals (dynamic operation) and stationary terminals (static operation). The static operation is typical for a handheld mobile terminal and the dynamic operation for a vehicle-mounted mobile terminal. According to the TETRA standard, receiver sensitivity values must be at least [3]:

- Receiver sensitivity for BS: -115 dBm for static operation and -106 dBm for dynamic operation.
- Receiver sensitivity for MS: -112 dBm for static operation and -103 dBm for dynamic operation.

The consideration of static or dynamic operation also impacts on the computation of the Fading Margin (FM) considered in the link budget [4]. For the dynamic case, fast fading is assumed to be averaged out over the transmission burst so that fading is simply the log normally distributed slow fading. Therefore, in this case the FM is calculated using a lognormal distribution. On the other hand, for the static case, fast fading must be considered together with slow fading. Therefore, in this case the FM is calculated using a Suzuki distribution, which is formed from the addition of lognormal and Rayleigh distributions.

For both dynamic and static cases, the FM is calculated for a given cell edge coverage probability (P_{Cell_Edge}). The cell edge coverage probability corresponds to the reliability of coverage that you are planning to achieve at the cell edge. For example, a cell edge coverage probability of 75 % means that the users located at the cell edge will receive adequate signal level during 75 % of the time. Therefore, a coverage prediction with a cell edge coverage probability of x % means that the signal level predicted on each location is reliable x % of the time, and the overall predicted coverage area is reliable at least x % of the time.

Based on the above, the formula for the calculation of the FM for the dynamic case is as follows [5]:

$$FM(dB) = \sigma \cdot Q^{-1}(P_{out})$$

where σ is the standard deviation for lognormal distributed slow fading in dB, P_{out} is the outage probability given by $P_{out} = 1 - P_{Cell_Edge}$ and the Q-function is the complementary cumulative density function (CDF) of a standard Gaussian distribution defined as:

$$Q(a) = \frac{1}{\sqrt{2\pi}} \int_a^{\infty} \exp\left(-\frac{x^2}{2}\right) dx$$

For the static case, the FM must account for the combination of both large-scale and small-scale fading. One possibility to compute the total FM is to just add up the fading margin for a lognormal (as done for the dynamic case) and the fading margin of the Rayleigh distribution. This approach leads to the following expression [5]:

$$FM(dB) = \sigma \cdot Q^{-1}(P_{out}) - 10 \log_{10}(\ln(1 - P_{out}))$$

The above method for the computation of the FM in the static case is commonly used because of its simplicity, but overestimates the required FM. A more accurate method [5] is based on the use of the CDF of a Suzuki distribution for the signal field strength (r), which relates the admissible outage probability to the necessary mean field strength (r_{min}) as follows:

$$P_{out} = cdf(r_{min}) = \int_0^{\infty} \left(1 - \exp\left(-\frac{\pi \cdot r_{min}^2}{4r^2}\right)\right) \frac{20/\ln(10)}{r\sigma\sqrt{2\pi}} \exp\left(-\frac{(20\log_{10} r - \mu)^2}{2\sigma^2}\right) dr$$

where μ represents the mean-dB value of the signal field strength distribution (which is indeed related to the mean-dB value of received signal power computed as $\mu + 10\log(4/\pi)$) and the FM is given by $\frac{\mu^2}{r_{min}^2}$. Therefore, given μ and the standard deviation σ associated with the slow fading, a plot with the values of the outage probability can be computed by evaluating the above equation for different values of r_{min} . From such a plot, the value of r_{min} . (and consequently the FM value for the static case) that satisfies a given P_{out} can be selected.

6.2.2 Characterisation of the BS traffic load and associated performance metrics

The BS traffic capacity (A) is calculated either from the Erlang B or Erlang C formula. The input for this calculation is the two out of the three parameters shown below and the output is the third:

1. The BS traffic capacity (A)
2. The number of available traffic channels (C). The traffic channels are calculated as

$$C = N_{TRX} \cdot 4 - \#MCCH$$

3. The required Grade of Service (GoS) or Blocking Probability (P_B).

The **Erlang B formula** is given by:

$$GoS = P_B = \frac{\left(\frac{A^C}{C!}\right)}{\left(\sum_{k=0}^C \frac{A^k}{k!}\right)}$$

The trunking efficiency is calculated as $n_t = \frac{A \cdot (1 - P_B)}{C}$

The **Erlang C formula** is given by:

$$GoS = P_Q = \frac{A^C}{A^{C+1} C! \left(1 - \frac{A}{C}\right) \left(\sum_{k=0}^{C-1} \frac{A^k}{k!}\right)}$$

where P_Q is the probability that a call is put on the queue. The probability that a queued call waits for more than t is given by:

$$P_w(t) = \text{Pr ob}(T_Q > t) = e^{-\left(\frac{C-A}{T}\right)t}$$

where T is the average call duration.

6.2.3 Dimensioning of the BS resources

To dimension the number of BS and number of TRXs of a network both coverage and traffic requirements shall be fulfilled.

Coverage requirements are determined by the area of coverage, specified in the coverage area definition process. It is defined either as raw input value or after calculation according to provided area boundaries coordinates.

In order to have a realistic calculation of the traffic load in the radio access it is needed to have a predefined traffic user profile which should take into consideration the statistical and network parameters such as:

- Total active call duration
- Maximum number of users
- User distribution within the operational network
- User distribution data (traffic distribution maps)

On this basis, traffic requirements are determined by the user traffic requirements definition process and is calculated as

$$\text{Traffic Re quirements} = N_{users} \cdot TP_{users}$$

The following steps have to be followed for the network dimensioning process:

1. Calculation of an initial number of BS. This is defined by the following equation:

$$\#BS = \frac{CoverageArea}{\frac{3 \cdot \sqrt{3}}{2} \cdot R^2}$$

where R is the cell range.

2. Calculation of the Traffic Load per BS (TL_{BS}). This is defined by

$$TL_{BS} = \frac{TrafficRequirements}{\#BS}$$

3. Comparison of Traffic Load per BS (TL_{BS}) with Traffic Capacity per BS (A)

- a. If $TL_{BS} \leq A$ then optimal solution is found.
- b. If $TL_{BS} > A$ then increase the number of TRXs (N_{TRX}) in all BS by 1. Recalculate the traffic capacity per BS and go to step 1.
- c. If number of TRXs per BS reaches a given threshold ($N_{TRX} = 4$) and $TL_{BS} > A$ then increase the number of BS ($\#BS$) by 1 and reset the number of TRX to initial value. Recalculate the TL_{BS} and restart the optimal solution research.

In addition to the previous computations, the tool provides some other intermediate useful metrics such as the Link Unbalance Factor (F_{LU}). This parameter is calculated as follows. First, the UL/DL link balance of the system is calculated according to:

$$MaxAllowablePathLoss_{(DL)} =$$

$$EIRP_{(BS)} - (Rx_{sens(MS,static/dynamic)} - G_{ant(MS)} - G_{Div(MS)} + L_{con(MS)} + L_{Cab(MS)} + L_{other(MS)})$$

$$MaxAllowablePathLoss_{(UL)} =$$

$$EIRP_{(MS)} - (Rx_{sens(BS,static/dynamic)} - G_{ant(BS)} - G_{Div(BS)} + L_{con(BS)} + L_{Cab(BS)} + L_{other(BS)})$$

Note that the calculation of the maximum allowable path loss figure depends on whether terminals are assumed to be moving or stationary, as respectively accounted within the receiver sensitivity parameters for the dynamic or static operation cases.

If $MaxAllowablePathLoss_{(DL)} > MaxAllowablePathLoss_{(UL)}$ the system is characterized as UL limited.

If $MaxAllowablePathLoss_{(DL)} < MaxAllowablePathLoss_{(UL)}$ the system is characterized as DL limited.

If $MaxAllowablePathLoss_{(DL)} = MaxAllowablePathLoss_{(UL)}$ the system is characterized as balanced.

From the previous expressions, F_{LU} is straightforwardly derived as:

- $F_{LU} = MaxAllowablePathLoss_{(DL)} - MaxAllowablePathLoss_{(UL)}$ if System is UL limited
- $F_{LU} = 0$ otherwise

6.3 ISI capacity dimensioning

6.3.1 Characterisation of the ISI traffic load and associated performance metrics

An ISI connection between two interconnected PPDR networks can be used to offer the following services to terminals that migrate from their home Switching and Management Infrastructure (SwMI) to a foreign SwMI [6][7][8]:

- **Individual calls (IC).** The ISI support for individual call enables calls to be set-up from a user registered in one SwMI to another user registered in another SwMI. The following cases can be distinguished: (1) Individual call to a subscriber from the home SwMI (while migrated); (2) Individual call to a subscriber from the visited SwMI (while migrated); (3) Individual call to a subscriber from another SwMI (not a subscriber home nor current SwMI) (while migrated); and (4) Individual call to a subscriber (not migrated).
- **Group calls (GC).** The ISI support for group calls enables point-to-multipoint calls to be set-up between users located in more than one SwMI. The home SwMI of a group will always be the controlling SwMI for a group call. During group call set-up, the group home SwMI will inform each participating SwMI. It is up to the participating SwMI to connect the call to the attached users in that SwMI. Two cases are distinguished: (1) Group call when located in group home SwMI; and (2) Group call when not located in group home SwMI. Broadcast calls can also be considered as a special type of group call. Broadcast calls are a type of group calls whereby only the calling party is entitled to transmit, while the rest of subscribers are only allowed to receive the information (one-way point-to-multipoint). Operational leaders and/or dispatchers may need launching broadcast calls in order to warn operational people, staying in a specific geographic area on the field, about an immediate danger, or to notify it about essential and urgent information.
- **Emergency calls (EC).** Emergency calls should be presented and treated over the ISI maintaining the emergency priority. In international talkgroups, emergency calls should be presented to all involved dispatchers, all dispatchers having equal rights to handle this call. Four different situations can be distinguished: (1) Emergency call to a home group while in a foreign SwMI; (2) Emergency call to a foreign group when registered in the same foreign SwMI; (3) Emergency call to a foreign group when registered on a different foreign SwMI; and (4) Emergency call to a foreign group when registered in home SwMI.
- **Telephone Calls (TC).** Telephone calls might be enabled for migrated terminals. In the case of outgoing calls (MS to PSTN), these should be routed via the local gateway to the public telephone network. In the case of incoming calls (PSTN to MS), these will be routed over the ISI to the destination subscriber when the call originates from the gateway in the home SwMI of the called MS.
- **Short Data Service (SDS) / Status messaging.** The ISI support for SDS enables point-to-point or point-to-multipoint short data messages to be passed between TETRA users located in more than one TETRA SwMI. SDS messages are transported using call unrelated signalling. A message is transparently taken as presented by the originating SwMI and transported to the peer SwMI. Status/SDS messages can be either individually addressed or group addressed. SDS are used to exchange multiple types of information such as text messages, status messages (sending pre-programmed status from a terminal to a talk group or to the dispatcher(s) of the selected talk group) and short data messages related to mobile applications (e.g., geolocation coordinates, small pictures, terminals remote control from dispatching via AT commands over SDS).

In addition to the above services that support end-user information exchange (voice and/or short data messages), the support of **Mobility Management (MM)** and **Supplementary Services (SS)**

procedures between the interconnected SwMIs also generate some amount of traffic load over the ISI link.

MM is a set of various signalling procedures for user identity registration and location updates. In particular, the MM services extended over the ISI may include migration, de-registration, profile update, authentication, Over The Air Re-keying (OTAR), group attachment and detachment, database recovery and group linking. Several variants of the migration scenario exist. Mainly, they differ in the type of profiles exchanged between the involved SwMIs. In the simplest migration scenario the visited SwMI uses a predefined profile for the user rights. Lengthier scenarios require the exchange of the actual user profile with the home SwMI.

SS are services that modify or supplement a main service (e.g., individual call, SDS, group call). The ISI specification allows for signalling information exchange between two SwMIs for the control of some of the supplementary services (e.g., Calling Line Identification Presentation (CLIP), Talking Party Identification (TPI), Late Entry (LE), Pre-emptive Priority Call (PPC), Air-Ground-Air operation (AGA), Dynamic Group Number Assignment (DGNA)).

It is also worth noting that **Packet Data** (PD) services are not supported over the ISI connection. Indeed, IP PD services are covered by a separate standard called the Inter-Packet Interface (IPI).

Based on the above description of services, an illustration of the composition of the traffic exchanged over the ISI is depicted in Figure 2.

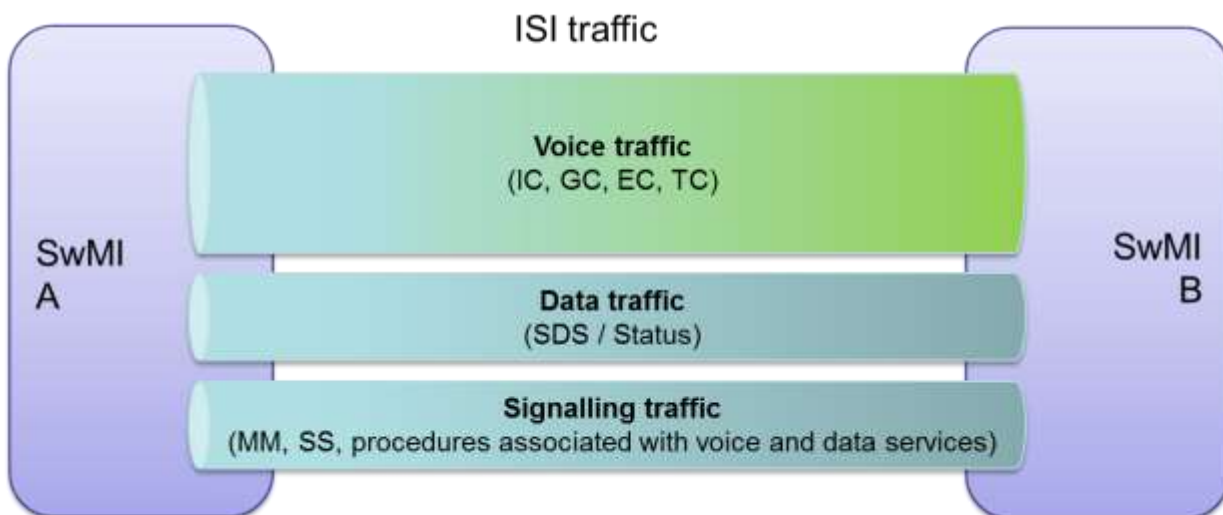


Figure 2. Composition of ISI traffic

The approach followed for the characterisation of the voice traffic and data traffic in the dimensioning tool, along with the associated traffic models and dimensioning metrics, is described in the following. Signalling traffic is not modelled as a separate component but accounted as an overhead to the voice and data traffic.

6.3.1.1 Voice traffic

The two central parameters used to characterise voice traffic are:

- Call arrival rate at the peak period ($\lambda_{V,ISI}$ in call/s)
- Average service time or hold time (T_{ISI} in seconds)

With this information, the traffic load in Erlangs is computed. An Erlang (E) is a unit of telecommunications traffic measurement. Strictly speaking, an Erlang represents the continuous use of one voice path. In practice, it is used to describe the total traffic volume at the peak period (e.g., in the busiest hour). In this way, the offered voice traffic load is computed as:

$$\text{Offered voice traffic in Erlangs over the ISI link} = A_{v,ISI} = \lambda_{v,ISI} \cdot T_{ISI}$$

Considering that there might be a limitation in the maximum number of voice calls/circuits ($N_{v,ISI}$) that can be simultaneously active across the ISI link, it could happen that a given call cannot be established. In this case, the call request can be put on hold and wait until resources become available or the call request can just be blocked or rejected. Depending on how the system operates, distinction can be made between loss-systems and waiting time systems (or a mixture of these if the number of waiting positions (buffer) is limited). These two cases can be modelled through [9]:

- Erlang B Model. This represents a loss-system. In this case, the main performance metric for capacity dimensioning is the blocking probability (P_B), defined formally as the number of lost calls over offered calls.
- Erlang C Model. This represents a waiting time system. In this case, two main performance metrics for capacity dimensioning are the probability that a call is put on a queue (P_Q) and the probability that a queued call waits for more than a given time T_w , denoted as $P_w(t_q > T_w)$.

The formulas for the computation of above performance metrics together with other relevant parameters that can be assessed from the application of both Erlang-B and Erlang-C models are provided in Table 2.

| Parameter | Notation | Formula |
|------------------------------------------------------------------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------|
| Probability for a call to be put in the queue and so experience delay (Erlang call-waiting formula) | P_Q | $= \frac{N_{v,ISI} \cdot P_B}{N_{v,ISI} - A_{v,ISI} (1 - P_B)}$ |
| Average delay (held in queue) | T_Q | $= \frac{T_{ISI}}{N_{v,ISI} - A_{v,ISI}} P_Q$ |
| Average number of waiting calls | N_Q | $= \frac{A_{v,ISI}}{N_{v,ISI} - A_{v,ISI}} P_Q$ |
| Probability of queuing delay exceeding T_w seconds | $P_w(t_q > T_w)$ | $= P_Q \cdot e^{- (N_{v,ISI} - A_{v,ISI}) \left(\frac{T_w}{T_{ISI}} \right)}$ |
| Probability of j or more waiting calls | $P_w(n_Q > j)$ | $P_Q \cdot \left(\frac{A_{v,ISI}}{N_{v,ISI}} \right)^j$ |
| Erlang lost-call formula (P_B) (Probability that a call request is lost when there is no waiting queue in the system) | P_B | $= \frac{\left(\frac{A_{v,ISI}^N}{N_{v,ISI}!} \right)}{\left(\sum_{k=0}^{N_{v,ISI}} \frac{A_{v,ISI}^k}{k!} \right)}$ |

Table 2. Formulas for the characterisation of voice traffic for both loss-systems and waiting time systems

Considering that voice traffic across the ISI link is made up of different types of voice services, call arrival rate (λ) and average service time (T) can be defined in the IDT separately for each type of voice service: IC, GC, EC and TC. Assuming that each of these traffic flows are independent processes, the properties of the so called multi-dimensional Erlang-B [9] can be used to estimate the overall blocking probability considering the aggregate input traffic computed as follows:

$$A_{v,ISI} = \sum_{i \in (GC, IC, EC, TC)} A_{v,ISI}^{(i)} = \sum_{i \in (GC, IC, EC, TC)} \lambda_{v,ISI}^{(i)} \cdot T_{ISI}^{(i)}$$

While the above formulation is needed to compute $N_{v,ISI}$ to satisfy the desired performance metrics given input traffic $A_{v,ISI}$, the needed link capacity will depend on the technology used (TETRA ISI or IP ISI) and, in the latter case, the characteristics of the voice codecs. Different codecs can be considered to be supported between the ISI gateways. Codecs may vary in the sound quality, the bandwidth required, the computational requirements, etc. Some of the most popular standard voice codecs are:

- G.711. It's the default codec for fixed communications. Uses Pulse Code Modulation (PCM) and comes in two flavors: A-law and μ -law. It provides the best speech quality for narrowband (i.e., encoding of voice signals between 200-3400 Hz) codecs with a user data rate of 64 kb/s.
- G.729. It's one of the most popular narrowband codecs for IP-based fixed networks based on code-excited linear prediction (CELP). It provides similar speech quality characteristics to AMR 7.4 kb/s with a user data rate of 8 Kb/s.
- AMR (Adaptive Multi-Rate). The AMR codec encodes narrowband signals at variable bit rates ranging from 4.75 to 12.2 kbps. This allows the actual bit rate to be adapted to radio conditions and capacity requirements. AMR is the most popular narrowband codec for wireless networks. It is the required standard codec for UMTS wireless networks.
- AMR-WB (AMR Wide Band). The AMR-WB is the 7 kHz audio codec with better speech quality than narrowband codecs. It also adapts to radio conditions and capacity requirements with user data rates between 12.65 kb/s down to 6.60 Kb/s.

6.3.1.2 Data traffic

Status message service provides pre-defined messages from a limited list, while the user defined SDS allows transmitting messages up to 256 bytes of binary arbitrary data.

Status messages are 16 bits-long messages, thus their sending requires a minimum use of system resources. Up to 65535 numerical values could be encoded, being a range excluded for user applications because it is exclusively reserved for network use.

Regarding SDS, the TETRA standard states four types of SDS messages with different bit lengths. SDS types 1, 2 and 3, have a fixed size of 16, 32 and 64 bits respectively. The SDS type-4 is the one service with variable size up to 2,047 bits. SDS messages could also be used as data transport mechanism for different customer applications, such as Automated Vehicle Location (AVL), which is by far the most commonly used application in PMR networks today. In this case, SDS messages contain the current position of the terminal, which is sent at regular intervals to the control centre or a location server. The number of messages can vary importantly depending on the number of terminals being tracked as well as the required accuracy of the location information. Hence, tracking a field

operative may require the operative's position to be updated once every five minutes (12 times in an hour) while tracking a vehicle (a police car or an ambulance, for example) may require updates at a rate of 60 times in an hour or more.

From dimensioning purposes of the ISI link, status messages and SDS messages are treated equally as a data traffic aggregate with the following characteristics:

- $\lambda_{d,ISI}$ =Data message rate (messages / second)
- L_{ISI} =Average message size in bits
- $R_{d,ISI}$ =Average data bit rate in bit/s= $\lambda_{d,ISI} \cdot L_{ISI}$

A proper dimensioning must ensure that capacity for data message transmission between two points in a network, denoted here as $C_{d,ISI}$ in bit/s, is greater than the average offered bit rate $R_{d,ISI}$ trying to traverse between the two points. If the transmission capacity were not fast enough, a continuous build-up of data would occur in the buffer at the transmitting end, causing ever-increasing delays. In addition, the buffer must be large enough to temporarily store all waiting data. If the buffer is not big enough, then arriving packets will be lost at times when it is full. The arriving packets at these times simply overflow the buffer.

The Erlang C formula, though originally designed to model and dimension voice traffic, can easily be adapted to model data packets waiting to be transmitted across a statistically multiplexed transmission line [10]. To that end, the formulae of Table 2 may be adapted for data network dimensioning by substituting $N = 1$. This value corresponds to the assumption that there is only one line (i.e., one server in call-waiting formula language) carrying packets between any given pair of nodes in the data network. The link will have a given bit rate capacity, and the data flowing over the link could be thought of as being measured in Erlangs (the average usage of the line, assuming that permanent full usage of the single line would be equivalent to one Erlang). Thus, for example, an average bit rate of 1.5 Mb/s being carried on a 2 Mb/s link would be equivalent to 0.75 Erlangs.

The waiting time in this case is caused by other data packets already in the 'queue' or buffer. The call-waiting formula provides a means for calculating:

- The packet delay (D) caused by queueing buffers at intermediate nodes and limited line capacity; and
- the likely lengths of packet queues (and thus the size of queueing buffers which are required).

For a given traffic demand ($R_{d,ISI}$) and target latency (either average packet delay (\bar{D}_{ISI}) and/or the probability of buffer delay d exceeding D_{ISI} seconds), it is thus possible to calculate the required line capacity ($C_{d,ISI}$). Alternatively, knowing the capacity and the traffic demand, the latency performance can be estimated.

The formulas for the computation of above performance metrics based on the Erlang C model rearranged to data network traffic modelling are provided in Table 3.

| Parameter | Notation | Formula |
|---------------------------------------------------------------------------------------------------|-------------|---------------------------|
| Probability of message delay (Erlang call-waiting formula) Represents the average line loading | $A_{d,ISI}$ | $= R_{d,ISI} / C_{d,ISI}$ |

| | | |
|----------------------------------------------------------------|----------------------------|-------------------------------------------------------------------------------|
| during the peak period | | |
| Minimum transmission delay | D_{ISI}^{\min} | $= \frac{L_{ISI}}{C_{d,ISI}}$ |
| Average delay (packet held in buffer waiting for transmission) | \bar{D}_{ISI} | $= \frac{A_{d,ISI}}{1 - A_{d,ISI}} \cdot D_{ISI}^{\min}$ |
| Average number of waiting packets or frames in buffer | \bar{W}_{ISI} | $= \frac{A_{d,ISI}^2}{1 - A_{d,ISI}}$ |
| Probability of buffer delay d exceeding D_{ISI} seconds | $\text{Prob}(d > D_{ISI})$ | $= A_{d,ISI} \cdot e^{-(1 - A_{d,ISI}) \cdot \frac{D_{ISI}}{D_{ISI}^{\min}}}$ |
| Probability of j or more waiting packets | $P_w (w > j)$ | $= A_{d,ISI}^{j+1}$ |

Table 3. Formulas for the characterisation of data traffic based on the adaptation of the Erlang-C model

6.3.2 Dimensioning of the ISI resources

An ISI connection between two PPDR networks could consist of one or more sets of connections. A single connection to another SwMI is the simplest possible solution. Two or more geographically separate connections between pairs of SwMIs could allow resilience, and could reduce traffic backhauling requirements in some circumstances as well. However, it would introduce additional complexity, especially when visitors roam in the visited SwMI between points of connection of ISI. Therefore, the dimensioning tool assumes that the connection between two SwMIs will be a single connection from a single interface point on one SwMI to a single interface point on the other SwMI.

The bandwidth of the connection over which the ISI interface is deployed will depend on the expected traffic load among all interconnected SwMIs. This traffic load needs to be estimated for each pair of interconnected SwMIs. Voice traffic and data traffic are considered the two central components of this traffic load.

The protocol stacks used in the ISI interface will add an overhead to the required net traffic load (e.g., overhead due to IP/UDP/RTP protocols for voice traffic). In addition, the security solution deployed to protect ISI interface may cause an additional overhead (e.g., overhead due to the use of IP Security solutions –IPsec-). The overall ISI link capacity to be deployed in a reference SwMI connected to a number of SwMI is illustrated in Figure 3.

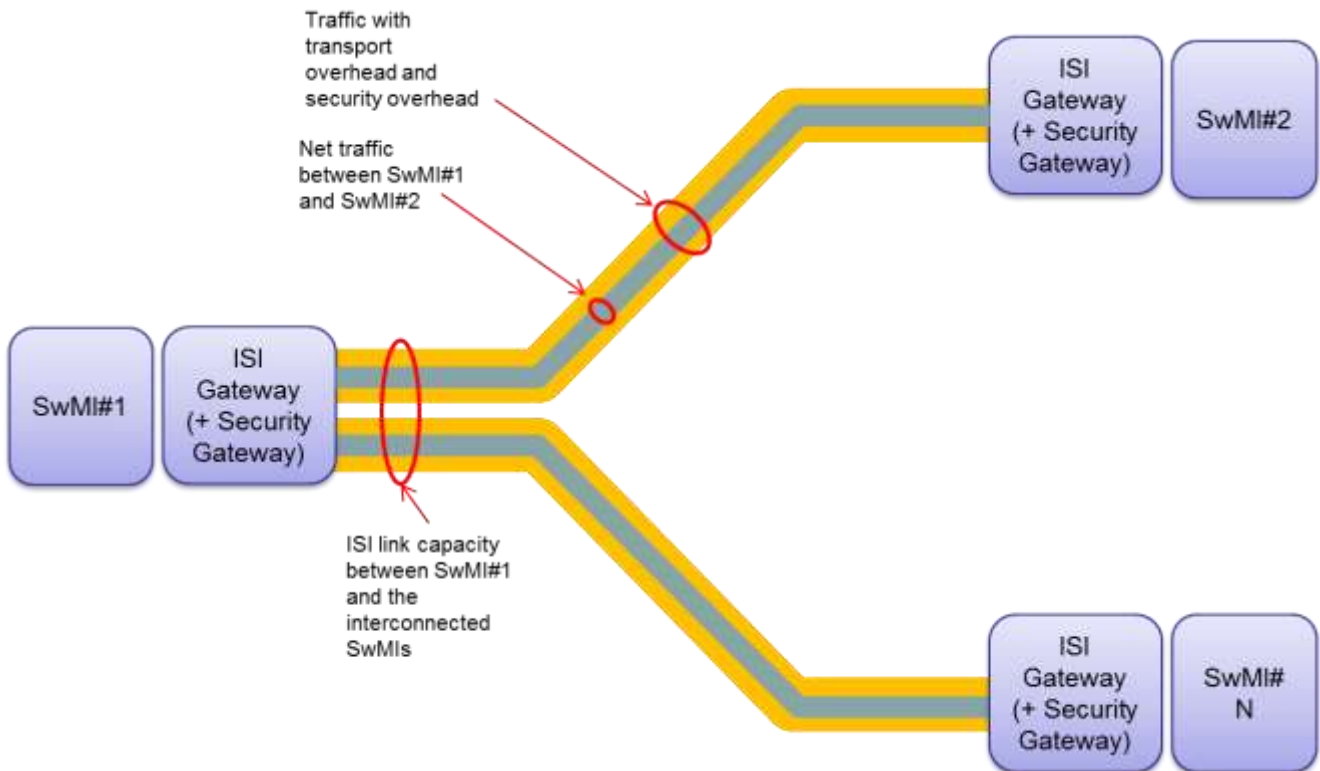


Figure 3. Overall ISI link capacity from a reference SwMI

The computation of the overall ISI capacity will depend on the ISI technology under consideration:

- TETRA ISI, as defined in ETSI EN 300 392-3-1 [2].
- IP ISI, under development in the ISITEP project [1].

The dimensioning process for each ISI technology is addressed below.

6.3.2.1 TETRA ISI over E-Carrier interconnection

In this case, speech frames are carried in an E1 channel of 64 kb/s; i.e. each inter system call requires a 64 kbps connection. All or a sub-set of E1 channels (30 channels: 1 to 15 and 17 to 31) shall be considered to be available for user information transport. It is assumed that one E1 at 2048 kb/s supports up to 30 simultaneous calls.

Unlike the IP-based data services, the E-Carrier system is a circuit-switched connection and it permanently allocates the capacity for a voice call for the entire duration. This, in one hand, ensures high audio quality because the transmission arrives with the same capacity and a short and fixed delay at all times.

The dimensioning process for the TETRA ISI interface between each pair of interconnected SwMIs consists of the following steps:

1. Dimensioning of voice capacity (based on the characterisation provided in Section 6.3.1.1):

- a. Define the call arrival rate at the busy hour ($\lambda_{v,ISI}$ in call/s) and average service time or hold time (T_{ISI} in seconds) for the different types of network traffic to be supported over the ISI.
 - b. Select the system model for Erlang-B or Erlang-C dimensioning. Accordingly, define the performance metrics (e.g., blocking probability (P_B) for Erlang-B or Probability of delay exceeding T_w seconds for Erlang-C).
 - c. Obtain the number of voice circuits $N_{v,ISI}$ based on formulation given in Table 2.
2. Dimensioning of data traffic capacity (based on the characterisation provided in Section 6.3.1.2):
- a. Define the message rate at the peak period ($\lambda_{d,ISI}$ in message/s) and the average message size in bits (L_{ISI}).
 - b. Establish either the average packet delay (\bar{D}_{ISI}) or the probability of the buffer delay d exceeding a given threshold (D_{ISI}) over the ISI link.
 - c. Compute the required line capacity ($C_{d,ISI}$).based on formulation given in Table 3.
 - d. Obtain the number of 64 kb/s circuits needed to provide the required line capacity (mechanisms for the aggregation of 64 kb/s into a single pipe are assumed to be in place) as follows:

$$N_{d,ISI} = \left\lceil \frac{C_{d,ISI}}{64 \cdot \alpha} \right\rceil$$

where $\lceil x \rceil$ represents the function that provides the closest integer that is equal or greater than x and α is a parameter between 0 and 1 that accounts for the net bit rate achievable over the 64 kb/s circuit for data transmission considering that some overhead will be introduced by the protocols used to transfer the SDS/status messages.

3. Compute the total number of E1 circuits as:

$$\text{Number of E1 circuits (2Mb/s) for the ISI connection} = \left\lceil \frac{N_{v,ISI} + N_{d,ISI} + N_{s,ISI}}{30} \right\rceil$$

This computation assumes that a number of E1 channels $N_{s,ISI}$, which value can be defined by the IDT user, are left available to support the TETRA ISI signalling (MM, SS and other signalling procedures associated with voice and data services).

6.3.2.2 IP ISI over packet transport interconnection

In this case the ISI resource calculator is used to estimate the bandwidth capacity required (C_{ISI}) to transport a given number of voice paths and data traffic through the IP based interconnection link.

It is assumed that voice traffic or SDS/status messages will be carried as the payload of IP packets. The overhead introduced by the different types of headers of the IP packet are accounted to compute

the capacity required (C_{ISI}). An illustration of the IP packet payload and the headers that may be in place is provided in Figure 4.



Figure 4. ISI voice and data traffic encapsulated in the payload of IP packets

The IDT can be configured with several codecs, characterised through the following parameters:

- Codec Bit Rate (Kbps). This is the number of bits per second that the codec transmits to deliver a voice call (codec bit rate = codec sample size / codec sample interval).
- Codec Sample Size (Bytes). This is the number of bytes captured by the Digital Signal Processor (DSP) at each codec sample interval. For example, the G.729 coder operates on sample intervals of 10 ms, corresponding to 10 bytes (80 bits) per sample at a bit rate of 8 Kbps (codec bit rate = codec sample size / codec sample interval).
- Codec Sample Interval (ms). This is the sample interval at which the codec operates. For example, the G.729 coder operates on sample intervals of 10 ms, corresponding to 10 bytes (80 bits) per sample at a bit rate of 8 Kbps (codec bit rate = codec sample size / codec sample interval).
- Voice Payload Size (Bytes). The voice payload size represents the number of bytes (or bits) that are filled into a packet. The voice payload size must be a multiple of the codec sample size. For example, G.729 packets can use 10, 20, 30, 40, 50, or 60 bytes of voice payload size.
- Voice Payload Size (ms). The voice payload size can also be represented in terms of the codec samples. For example, a G.729 voice payload size of 20 ms (two 10 ms codec samples) represents a voice payload of 20 bytes [(20 bytes * 8) / (20 ms) = 8 Kbps]
- PPS. PPS represents the number of packets that need to be transmitted every second in order to deliver the codec bit rate. For example, for a G.729 call with voice payload size per packet of 20 bytes (160 bits), 50 packets need to be transmitted every second [50 pps = (8 Kbps) / (160 bits per packet)].

The frequency at which the voice packets are transmitted have a significant bearing on the bandwidth required. The selection of the voice payload size is a compromise between bandwidth and quality. Lower sizes require more bandwidth. However, if the voice payload size is increased, the delay of the voice transmission increases as voice samples are buffered for a longer period of time before transmission. Furthermore, the system becomes more susceptible to packet loss.

In addition to the codec related parameters, the following parameters are also accounted in the dimensioning tool:

- Size of L2 headers. This depends on the L2 technology used in the ISI link. For example, when using Ethernet, 18 bytes for Ethernet L2 headers, including 4 bytes of Frame Check Sequence (FCS) or Cyclic Redundancy Check (CRC) are accounted.

- Size of IP and transport headers. In case of IPv4, 40 bytes for IP (20 bytes) / User Datagram Protocol (UDP) (8 bytes) / Real-Time Transport Protocol (RTP) (12 bytes) headers are considered for IP packets carrying voice frames. The option of using Compressed Real-Time Protocol (cRTP) is also accounted. cRTP reduces the IP/UDP/RTP headers to 2 or 4 bytes. In the case of data traffic, the IDT tool offers the possibility for the user to define the size of the transport headers that should be adjusted considering the particular encapsulation solution used for the exchange of this type of traffic.
- Use of IPsec. Security Protocols that form part of the IPsec framework are Authentication Header (AH) and Encapsulating Security Payload (ESP). These protocols can operate in either tunnel and transport modes (the tunnel mode encapsulates the full IP packet to be protected into another IP packet while the transport mode does not). The use of IPsec could add an overhead of 30 bytes per IP packet.
- Voice Activity Detection (VAD) features. With circuit-switched voice networks, all voice calls use 64 Kbps fixed-bandwidth links regardless of how much of the conversation is speech and how much is silence. With voice over IP networks, all conversation and silence is packetized. VAD features allows packets of silence to be suppressed. A typical connection could have around 50 % of silence periods. Over time and as an average on a high volume with tenths of calls, VAD can typically provide up to a 35 percent bandwidth savings. A VAD efficiency allows the IDT tool to account for the VAD savings.

The impact of the protocol headers is accounted by defining the protocol overhead factor as:

- Protocol overhead factor = ([L2 header] + [IPsec Header] + [IP/UDP/RTP header] + [packet payload size]) / [packet payload size]

For example, the required bandwidth for a G.729 call (8 Kbps codec bit rate) with cRTP, L2 Multi-Link Protocol (MP), no IPsec and the default 20 bytes of voice payload is:

- Total packet size (bytes) = (MP header of 6 bytes) + (compressed IP/UDP/RTP header of 2 bytes) + (voice payload of 20 bytes) = 28 bytes
- Protocol overhead factor = 28 / 20 = 1.4
- PPS = (8 Kbps codec bit rate) / (160 bits) = 50 pps
- Bandwidth per call = voice packet size (160 bits) * protocol overhead factor * 50 pps = 11.2 Kbps

Based on the above, the dimensioning process for the TETRA ISI interface between each pair of interconnected SwMIs consists of the following steps:

1. Dimensioning of voice traffic capacity:
 - a. Define the call arrival rate at the peak period ($\lambda_{v,ISI}$ in call/s) and average service time or hold time (T_{ISI} in seconds) for the different types of network traffic to be supported over the ISI.
 - b. Select the system model for Erlang-B or Erlang-C dimensioning. Accordingly, define the performance metrics (e.g., blocking probability (P_B) for Erlang-B or Probability of delay exceeding T_w seconds for Erlang-C).
 - c. Obtain the number of voice circuits $N_{v,ISI}$ based on formulation given in Table 2.
 - d. Define the codec characteristics

- e. Compute the protocol overhead factor per voice call = [packet payload size] / ([L2 header] + [IPsec Header] + [IP/UDP/RTP header] + [packet payload size])
- f. Compute the bandwidth for voice traffic as:

$$C_{v,ISI} = N_{v,ISI} * \text{Packet payload size} * \text{PPS} * \text{Protocol overhead factor} * \text{VAD efficiency}$$

2. Dimensioning of data traffic capacity

- a. Define the message rate at the peak hour ($\lambda_{d,ISI}$ in message/s) and the average message size in bits (L_{ISI}).
- b. Enter the protocol overhead factor for data traffic. This is used to increase the message size (L_{ISI}) to account for the protocol overheads.
- c. Establish either the average packet delay (\bar{D}_{ISI}) or the probability of the buffer delay d exceeding a given threshold (D_{ISI}) over the ISI link.
- d. Compute the required line capacity ($C_{d,ISI}$).based on formulation given in Table 3.

3. Compute the total capacity as:

$$\text{Bandwidth capacity required} = C_{ISI} = C_{v,ISI} (1 + \gamma_v) + C_{d,ISI} (1 + \gamma_d) + C_{s,ISI}$$

This computation assumes that there is some amount of capacity to support the TETRA ISI signalling (MM, SS and other signalling procedures associated with voice and data services). This additional capacity can be defined in the IDT as a percentage of the capacity required for voice and data traffic (by defining γ_v and γ_d) and as an fixed amount of capacity ($C_{s,ISI}$).

6.4 Logistic tool

6.4.1 Database technology

In order the application to be completed, the data should be organized in a relational database (RDBMS). The database to be used in IDT is MySQL database.

MySQL, is an open source relational SQL database management system. Based on the structured query language (SQL), which is used for the addition, removal, and modification of information / data in the database. MySQL runs on almost all platforms, including LINUX, UNIX, and WINDOWS.

The MySQL used in a wide range of applications, including data warehousing, e-commerce, databases on the Web, capture applications and distributed applications. More over, MySQL is used in increasingly integrated third-party software and other technologies.

Some of its advantages include the following:

- It is easy to use: While a basic knowledge of SQL is required—and most relational databases require the same knowledge—MySQL is very easy to use. With only a few simple SQL statements, you can build and interact with MySQL.

- It is secure: MySQL includes solid data security layers that protect sensitive data from intruders. Rights can be set to allow some or all privileges to individuals. Passwords are encrypted.
- It is inexpensive: MySQL is included for free with NetWare® 6.5 and available by free download from MySQL Web site.
- It is fast: In the interest of speed, MySQL designers made the decision to offer fewer features than other major database competitors, such as Sybase* and Oracle*. However, despite having fewer features than the other commercial database products, MySQL still offers all of the features required by most database developers.
- It is scalable: MySQL can handle almost any amount of data, up to as much as 50 million rows or more. The default file size limit is about 4 GB. However, you can increase this number to a theoretical limit of 8 TB of data.
- It manages memory very well: MySQL server has been thoroughly tested to prevent memory leaks.
- It supports Cluster & Cloud Services: MySQL on NetWare runs effectively with Cluster Services™, letting you add your database solution to a cluster. If one server goes down, MySQL on an alternate server takes over and your customers won't know that anything happened.
- It runs on many operating systems: MySQL runs on many operating systems, including Novell NetWare, Windows* Linux*, many varieties of UNIX* (such as Sun* Solaris*, AIX, and DEC* UNIX), OS/2, FreeBSD*, and others.
- It supports several development interfaces: Development interfaces include JDBC, ODBC, and scripting (PHP and Perl), letting you create database solutions that run not only in your NetWare 6.5 environment, but across all major platforms, including Linux, UNIX, and Windows.

MySQL runs over TCP/IP, making it highly accessible and capable of integrating into a Web environment. Clients across multiple platforms can access MySQL databases through the use of scripting languages such as PHP or Perl and C.

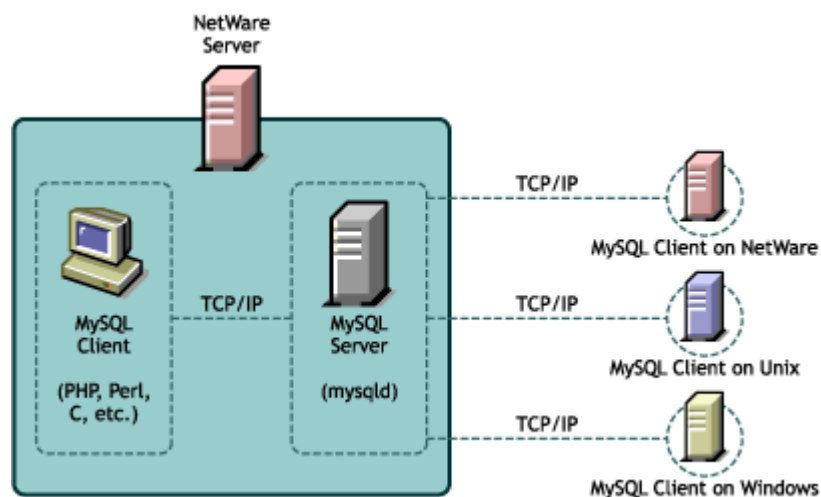


Figure 5. MySQL technology used to implement the logistic tool database

On a NetWare 6.5 server, MySQL can be installed with other Web components to provide an optimal Web architecture where you can build, deploy, and host Web database applications using PHP, Perl, EJBs, servlets, and JSPs. When you install the Web components included with NetWare, NetWare 6.5 is J2EE* compliant.

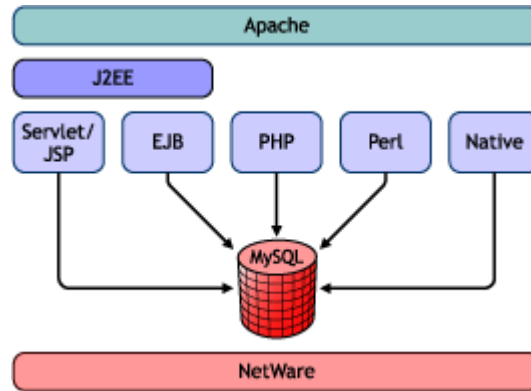


Figure 6. Web components that complement the MySQL settings

6.4.2 Network inventory structure

The logistic tool database is structured in a set of tables that allows for the characterisation of the different types of network resources considered in the dimensioning process:

| Database tables | Fields |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Terminal Equipment | <ul style="list-style-type: none"> • Type (e.g., Portable / Mobile) • Frequency Bands • Maximum transmit power • Sensitivity • Vendor • Model • Acquisition cost • Operating cost |
| Base Station Equipment | <ul style="list-style-type: none"> • Frequency Bands • Number of carriers • Maximum transmit power • Sensitivity • Vendor • Model • Acquisition cost |

| | |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <ul style="list-style-type: none"> • Operating cost |
| ISI Gateway Equipment: | <ul style="list-style-type: none"> • Interface type: TETRA ISI and/or IP ISI • Maximum number of interconnected networks: • Maximum voice traffic capacity (Simultaneous voice calls) • Maximum data traffic capacity (Maximum aggregate data rate, Maximum SDS/Status transfer rates) • VPN solution (None / IPSec) • Vendor • Model • Acquisition cost • Operating cost |
| Connectivity service | <ul style="list-style-type: none"> • Type: E1 leased line, L2 VPN, L3 VPN • Bit rate: Number of E1 circuits / Bit rate at L2 / Bit rate at L3 • Provider • Service Package • Activation cost • Operating cost |

Table 4. Information fields in the logistic tool database tables for the characterisation of the different types of network resources considered in the dimensioning process

6.4.3 Cost estimations

For each dimensioning exercise, the logistic tool allows the user to select the type of equipment that should be considered in that particular dimensioning process. This capability is exploited in several manners:

- The tool can automatically configure the default options shown in the different menus and parameters setting controls based on the characteristics of the selected equipment.
- If some amount of equipment is associated with given scenario as already available equipment, the result of the dimensioning process can be presented as a differential dimensioning analysis considering the existing infrastructures.
- Cost estimations can be provided considering the amount of required resources (obtained from the dimensioning sub-tools) and the cost information stored in the network inventory per equipment (e.g., acquisition costs and operating costs).

6.5 GUI features

IDT main GUI features are built with the use of HTML, JQuery and Bootstrap frameworks. The GUI elements are combined to create a web/browser based platform that offers a comfortable environment for user navigation and actions.

The user interface is developed with common best practice concepts in order to be user friendly and easy for navigation and operation. The essential part of the application is the structured navigation which assist the user when it is needed to set up the parameters and adjust the network settings.

Main elements of the GUI are Buttons, Forms, Menus, Message Areas, Popup Action Windows, The Map Mini ToolBox, Map Active Graphical Elements with use of layers. Examples of the usage of the above elements can be found below.

6.5.1 IDT Home Screen

The main IDT features and settings are available from this screen (illustrated in Figure 7). These are New Project Calculation, Setup Parameters, and History of Calculations/Projects performed buttons.

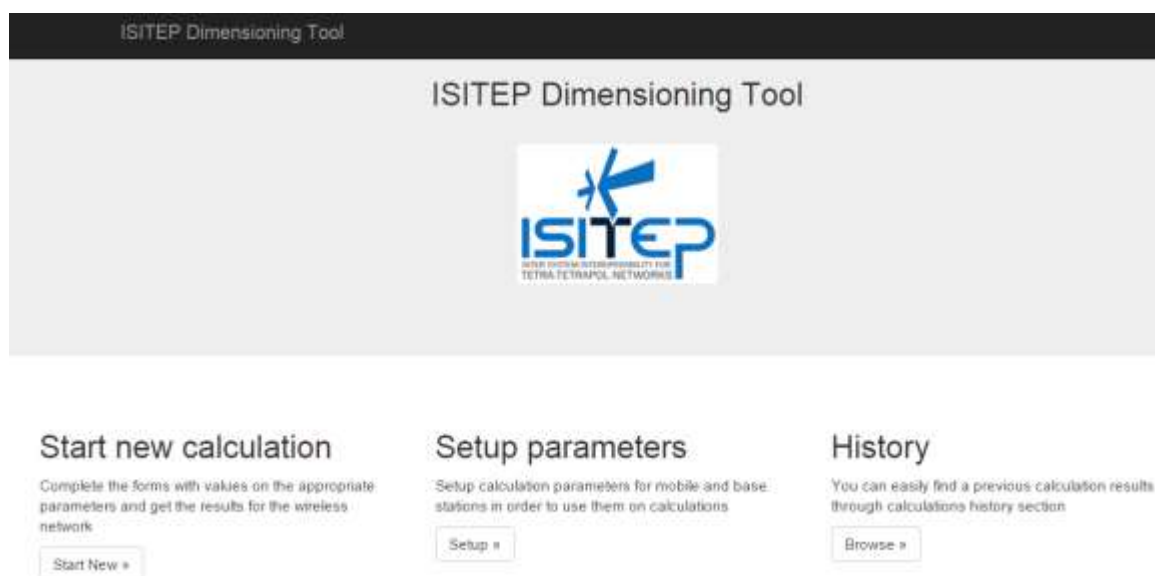


Figure 7. IDT Home Screen

By using the Setup Parameters option the tool is showing the general standard TETRA base station characteristics of different manufacturers. Additionally new models can be added with the respective parameters which will be used for the network dimensioning actions or to set up user defined parameters for each of the predefined base stations.

6.5.2 New Project Calculation GUI

As depicted in Figure 8, the GUI screen for a new calculation includes a site menu item which is offering to select the Wireless Technology, choose Area Types and specify the area which will be under analysis.

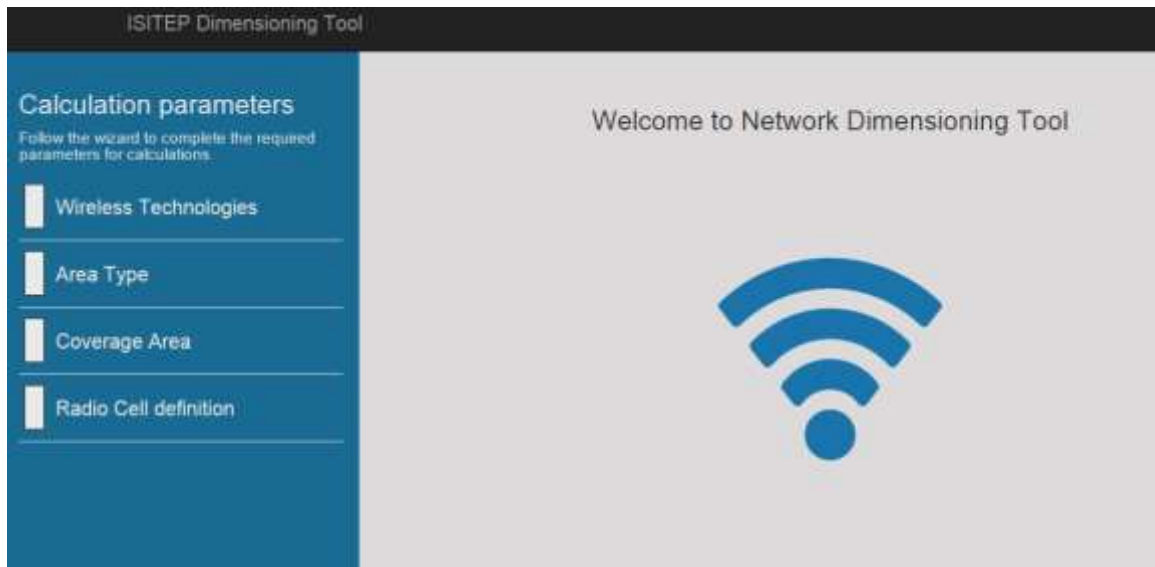


Figure 8. IDT New Calculation Home Screen

The user by clicking the items on the left side can see in the right side the relevant screen. GUI elements include forms, popup action windows and interactive map, as depicted in next figures 9-12.

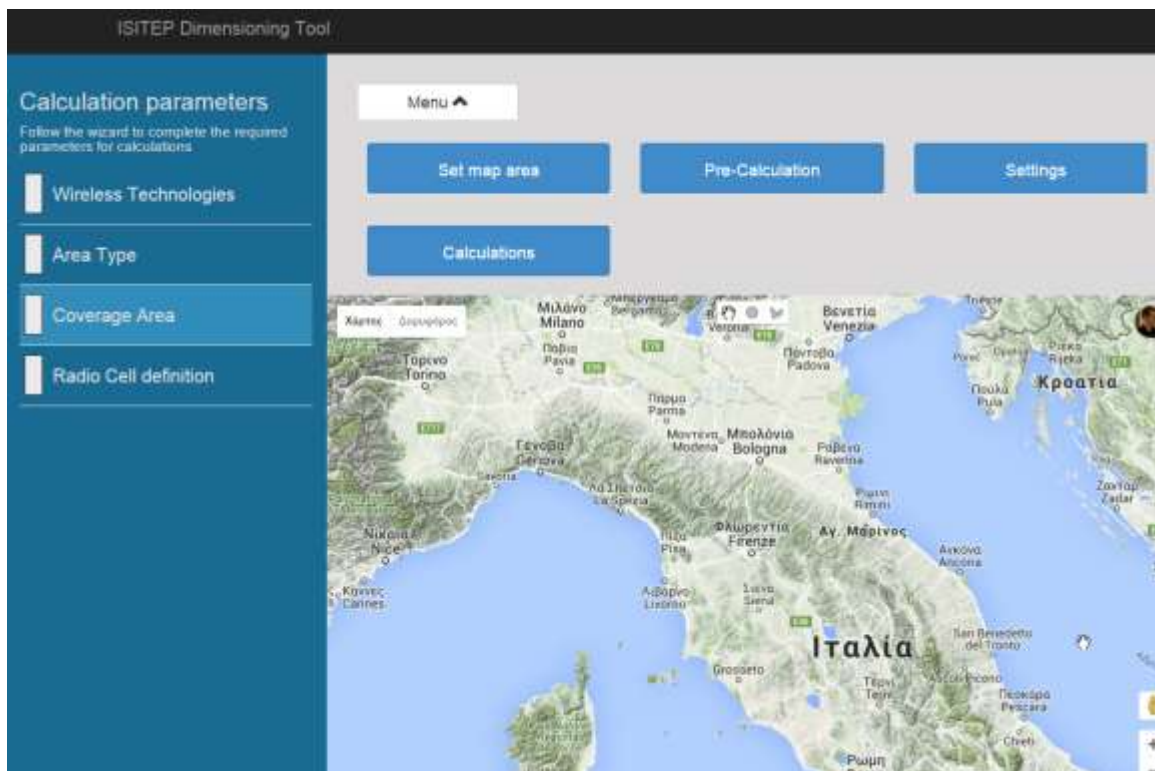


Figure 9. IDT Interactive Map

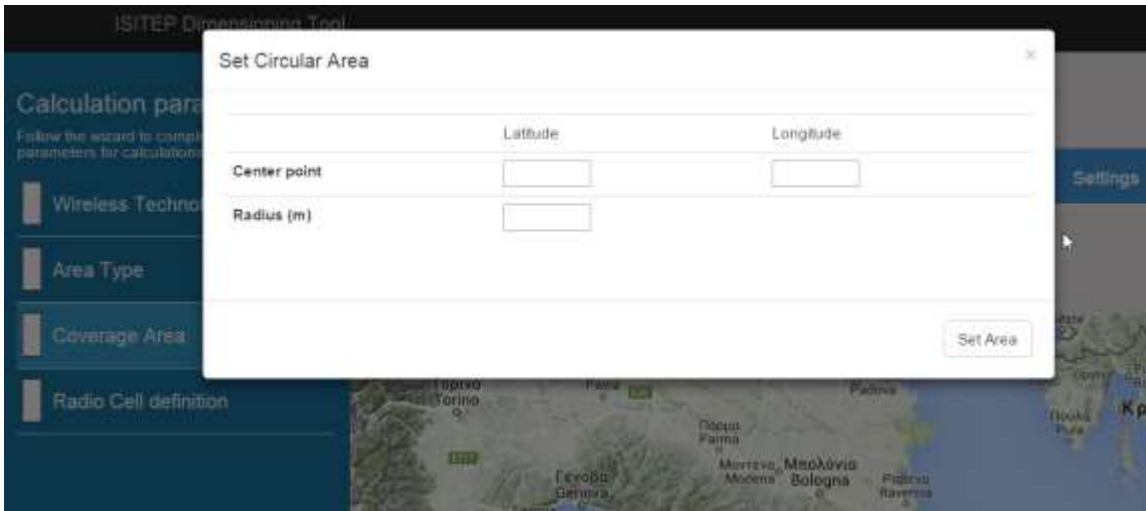


Figure 10. IDT Example Popup action window with form



Figure 11. IDT Map mini toolbox

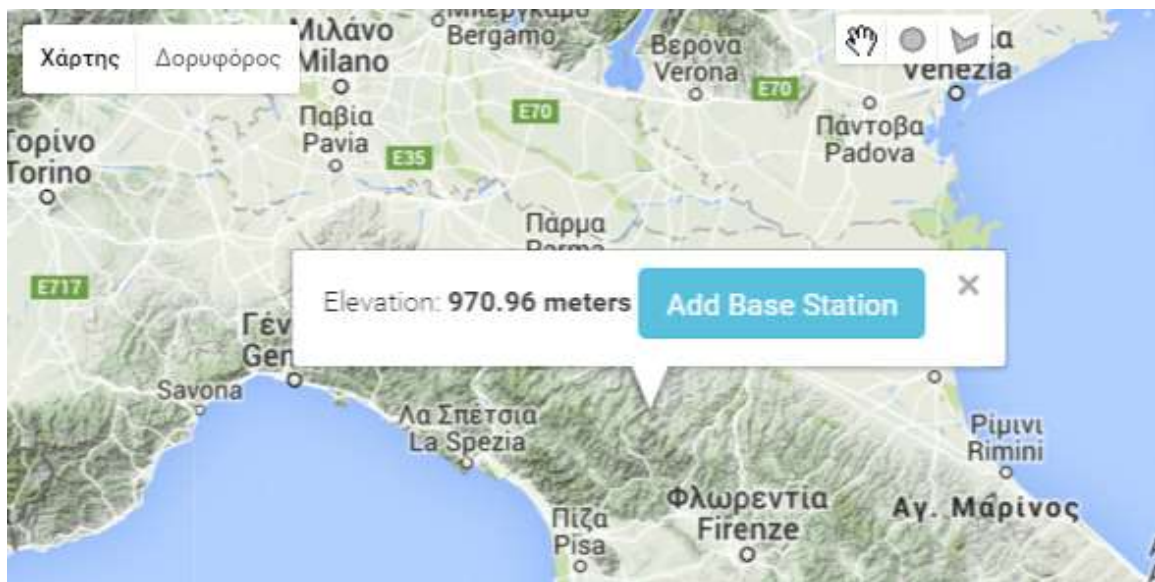


Figure 12. IDT Example Popup action window with information and action button

6.5.3 On Map Visual Representations

Some examples of the GUI components for on map visual representations are given in Figures 13-16, including features such as an interactive map visual coverage layer.

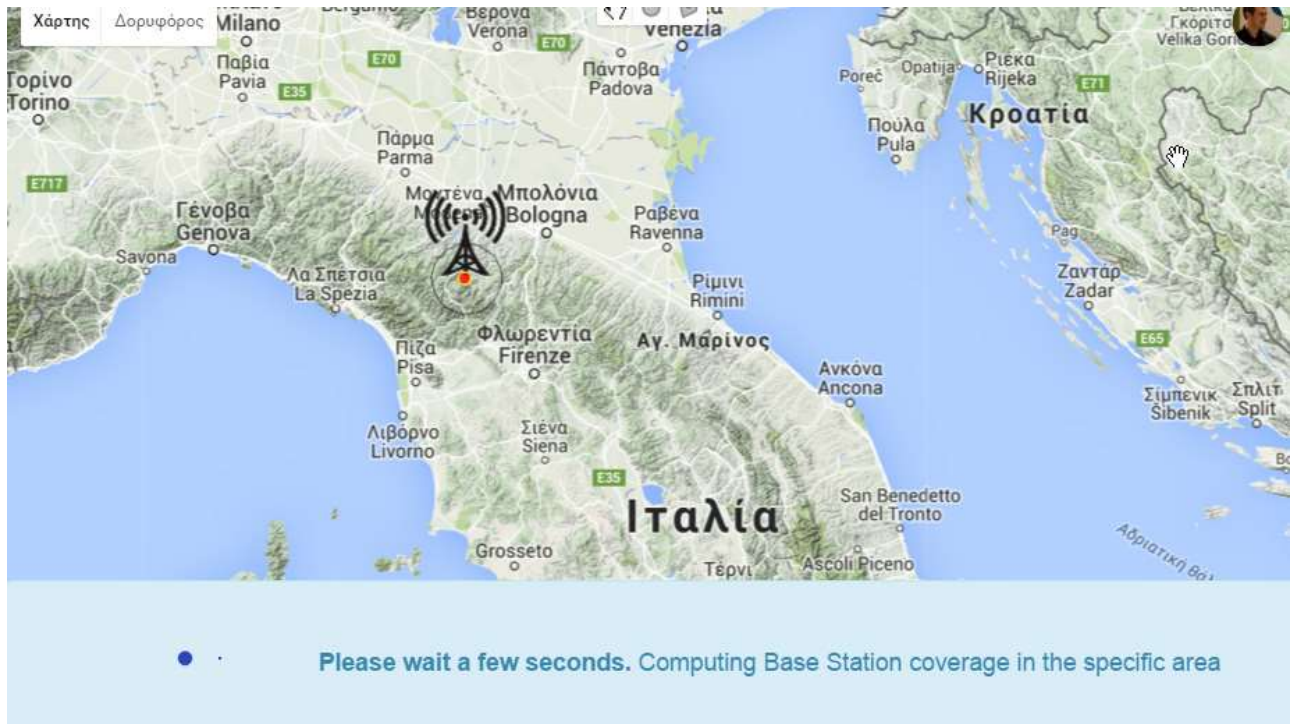


Figure 13. IDT Example Footer area system messages with user generated graphical elements on the map

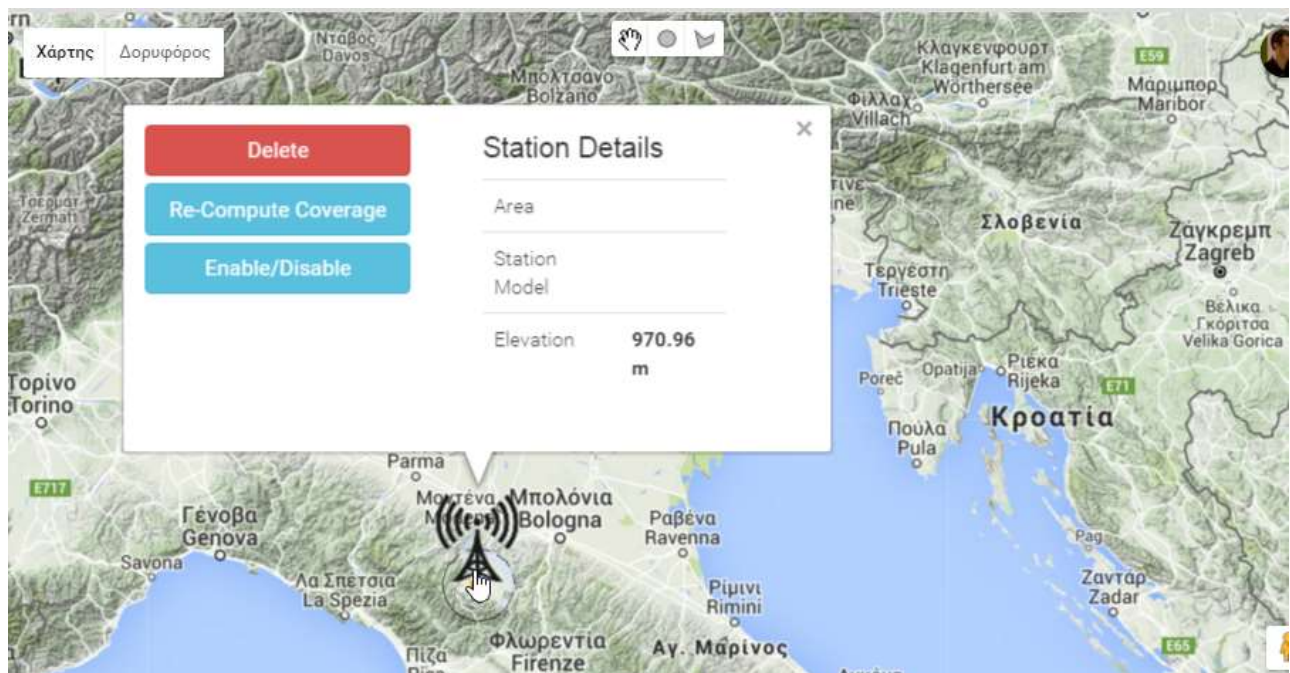


Figure 14. IDT Example Popup window with information, multiple actions and forms

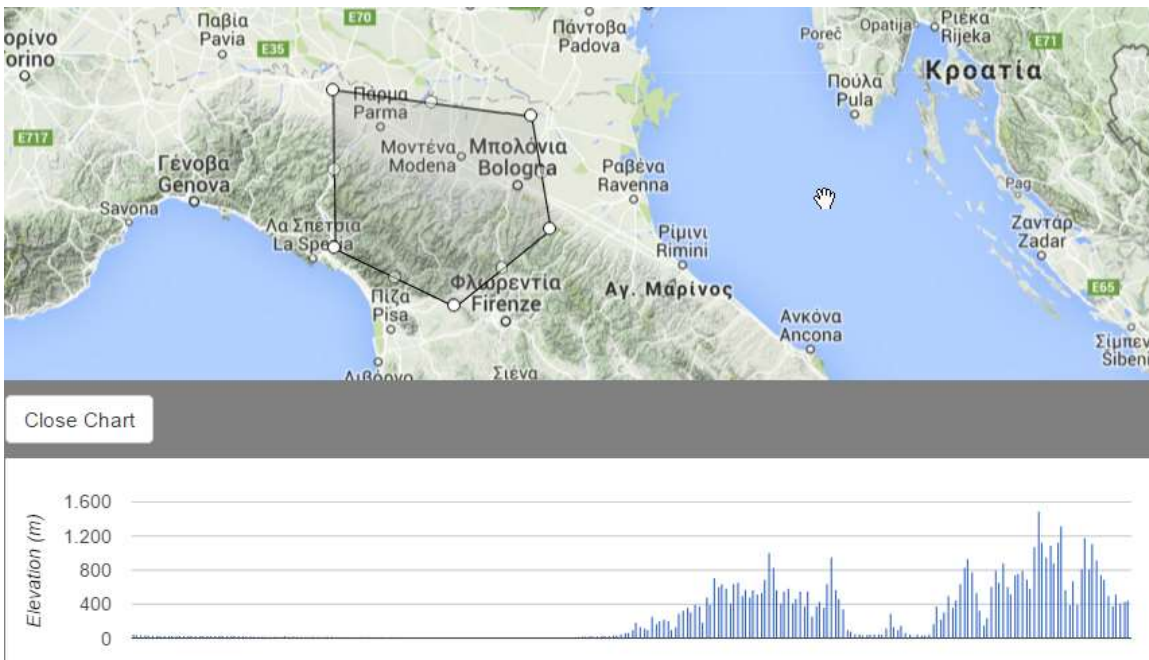


Figure 15. Example footer area information after using the map mini toolbox

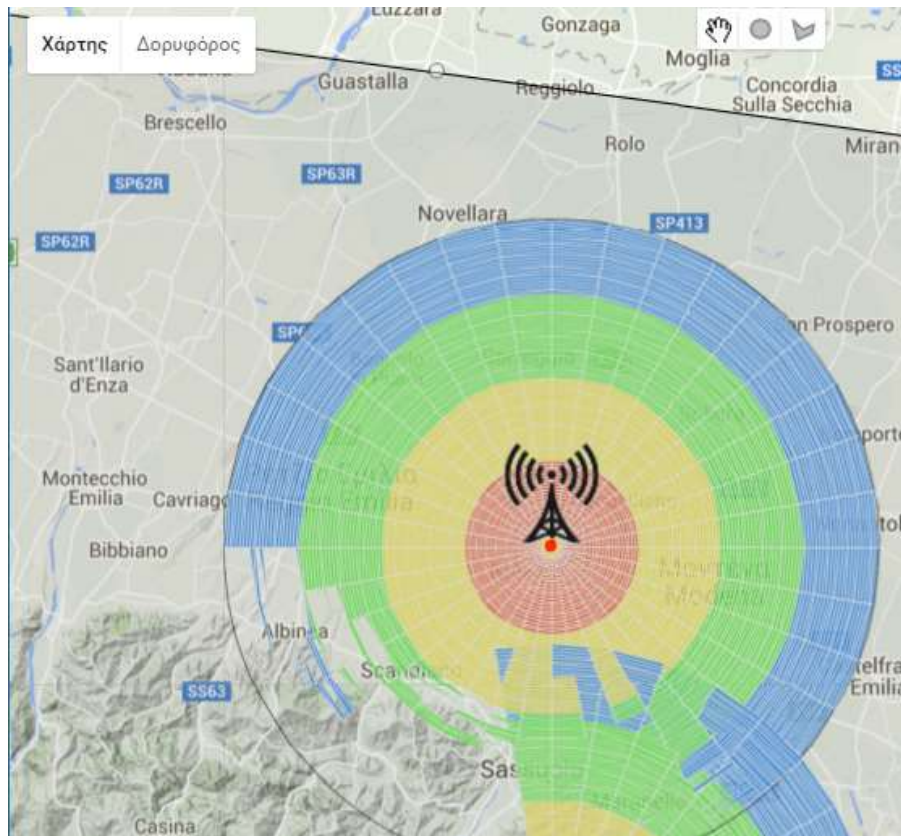
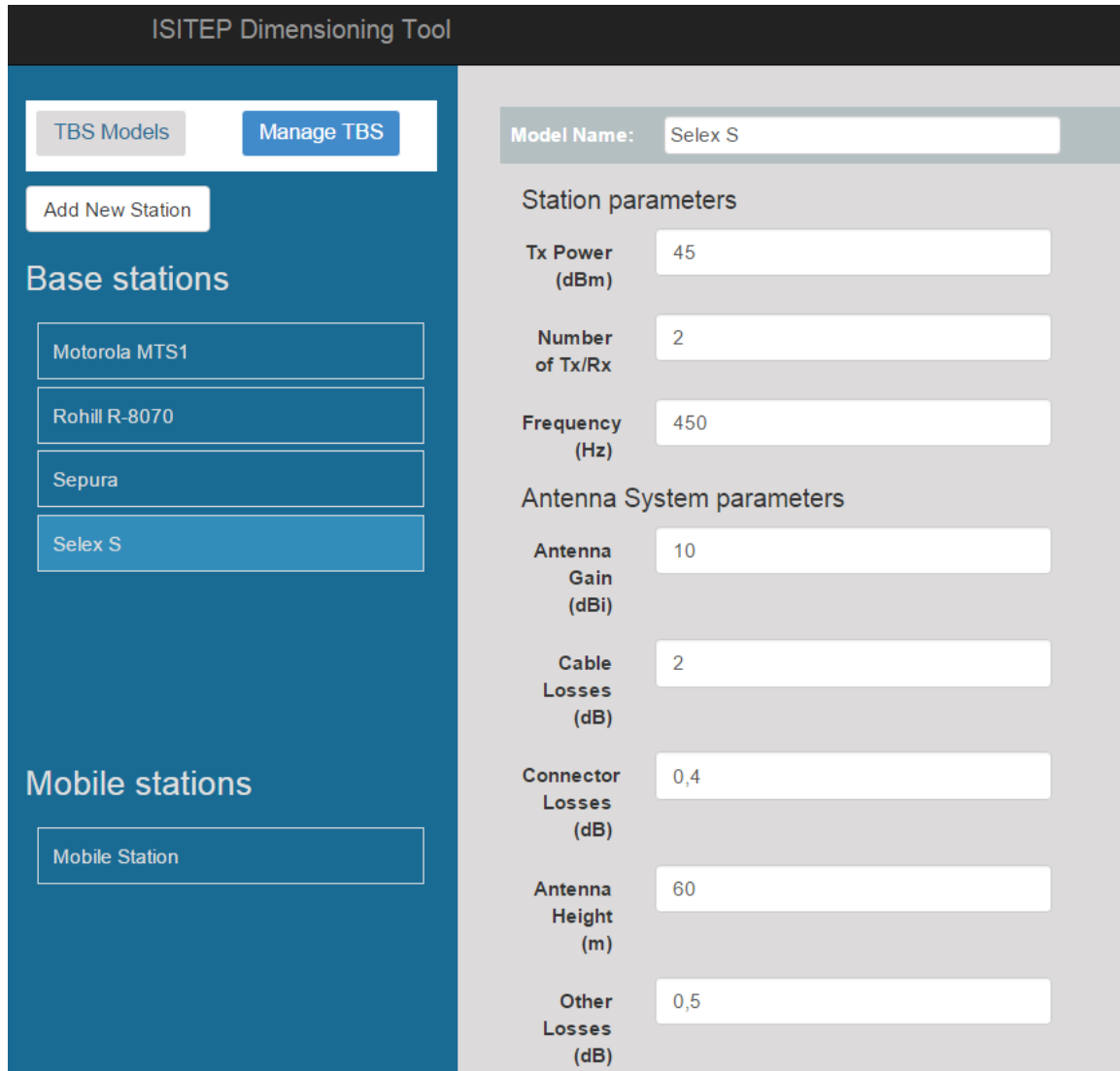


Figure 16. Example interactive map showing graphical presentation of information on new map layers

6.5.4 Parameters Forms

A number of parameters forms are supported, allowing the user to add data to the database for usage in the calculations. An example of these forms is depicted in Figure 17.



The screenshot shows the 'ISITEP Dimensioning Tool' interface. On the left, there is a sidebar with a 'Base stations' section containing a list of models: Motorola MTS1, Rohill R-8070, Sepura, and Selex S. Below this is a 'Mobile stations' section with a 'Mobile Station' button. The main area displays the 'Station parameters' for the selected 'Selex S' model. The parameters are as follows:

| Parameter | Value |
|----------------------------------|---------|
| Model Name | Selex S |
| Station parameters | |
| Tx Power (dBm) | 45 |
| Number of Tx/Rx | 2 |
| Frequency (Hz) | 450 |
| Antenna System parameters | |
| Antenna Gain (dBi) | 10 |
| Cable Losses (dB) | 2 |
| Connector Losses (dB) | 0,4 |
| Antenna Height (m) | 60 |
| Other Losses (dB) | 0,5 |

Figure 17. Example of setup parameters forms

7 CONCLUSION

This deliverable has provided the open public specifications of the Infrastructure Dimensioning Tool (IDT) being developed in the ISITEP project.

The main goal pursued through the development of the IDT is to create a user-friendly simulation tool for assisting engineering efforts in preliminary radio network design calculations, providing reliable input to decision makers for cost control handling and being applicable for various wireless technologies (TETRA, TETRAPOL) and ISI technologies (TETRA ISI and IP ISI). The IDT will provide estimations of the following communications resources: (1) Radio access infrastructure (TETRA/TETRAPOL radio access and transmission equipment needed in an intervention area) and (2) Interconnection infrastructure (ISI capacity to interconnect the TETRA/TETRAPOL networks involved in the joint or cross-border operations). Remarkably, the IDT is mainly conceived as a dimensioning tool, less complex than a Radio Planning Tool (RPT), and able to support a preliminary radio and network dimensioning process. Moreover, unlike existing RPTs, the dimensioning of the ISI link capacity is one of the distinguishing central features of the IDT.

The specifications of the IDT provided in the deliverable address (1) the scope and main functions of the IDT, (2) a description of inputs and outputs and (3) the detailed specifications of the models, computations and data templates used within the tool, together with the specification of its GUI features when relevant.

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