ROHILL

TetraNode Scalability and Performance

White paper

TetraNode

Issue 1.0, May 2017

1 Introduction

Rohill solutions are known for performance, flexibility, scalability, security and affordability. Also, the strong TetraNode system architecture, open standards-based interfaces and use of Commercial Off The Shelf (COTS) hardware and software solutions are widely recognised by the industry, our partners and end-users. Finally, the flexibility of the organisation allows for the development and supply of tailored solutions for all market segments. These are all based on a single TetraNode platform that supports dedicated solutions, in particular for Public Safety, Public Transport and Oil & Gas.

The Rohill core technology is a powerful IP based soft switch solution for mission-critical communications, based on open hardware and software platforms to create an expandable and future proof communications platform. The adoption of Linux for all core, application server and radio access platforms delivers carrier-grade performance, stability and availability. Rohill solutions offer five-times-nine (99,999%) availability when geographic redundancy and redundant links are applied.

Our technology leadership has been independently confirmed with TETRA Awards that include innovations for energy efficiency, the roadmap for LTE integration and projects that emphasize the power and flexibility of the TetraNode core and applications.

This white paper emphasizes on the scalability and performance of TetraNode networks. It covers the principle of operation of multi-node TetraNode networks, the scalability and performance that can be achieved, and how scalability, performance and reliability is verified by means of massive load testing within our premises and on-site before migration starts.

2 Architecture

The system architecture for a typical TetraNode solution for Public Safety is shown in the following diagram:

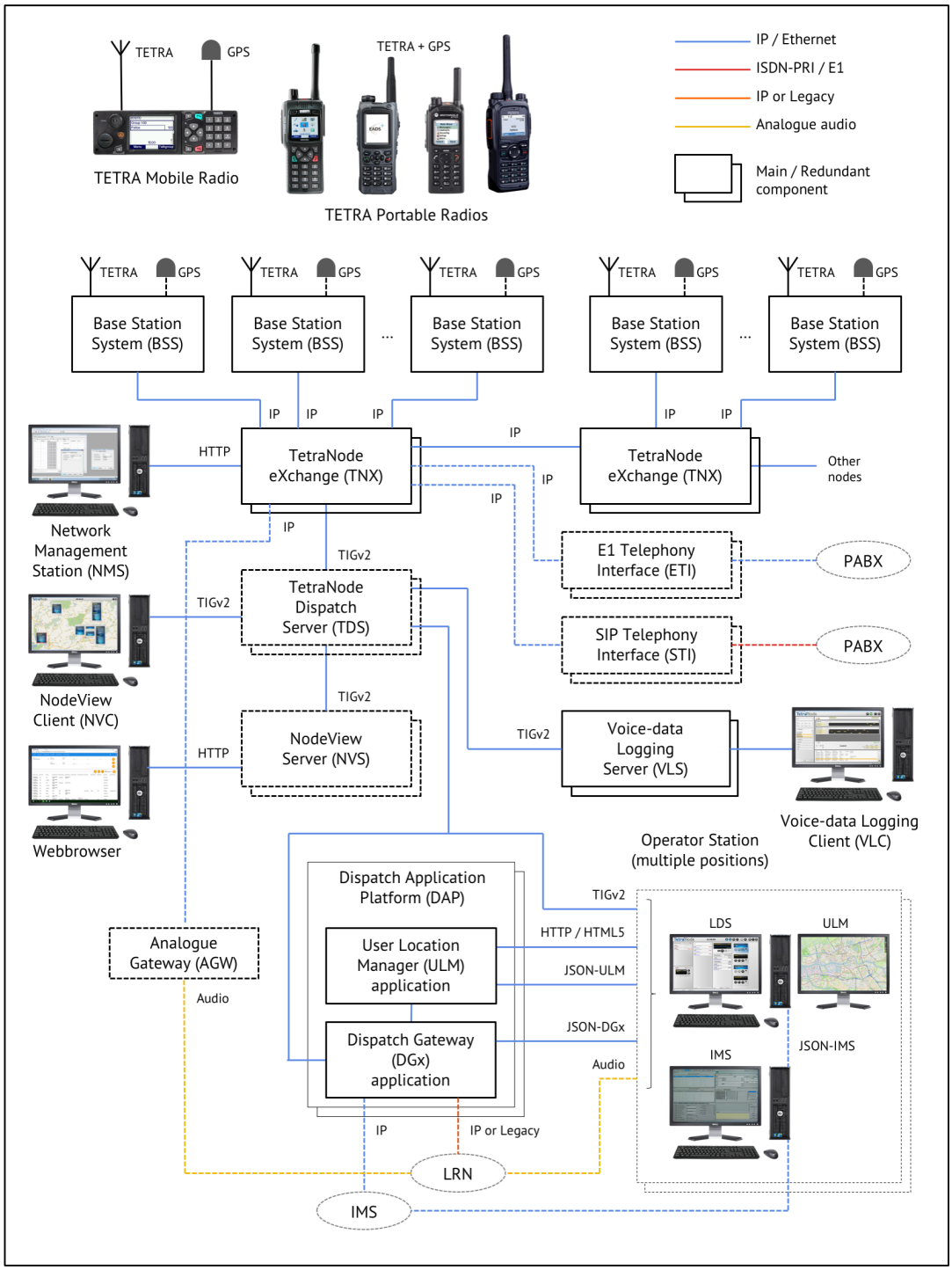

Figure 1 - System architecture TetraNode solution for Public Safety

This white paper focuses on the operation, scalability and performance of the TetraNode eXchange (TNX) and Base Station System (BSS) components. Please refer to the solution paper "TetraNode for Public Safety" on details on the other components and functionality of each individual component.

2.1 TetraNode eXchange

TetraNode solutions for Public Safety is built around the **TetraNode eXchange** (TNX).

The TetraNode eXchange manages all voice and data functionalities including call and resource management, the TETRA protocol stacks, databases for subscriber and configuration management, as well as support for telephony and dispatch interfaces.

The TNX runs on top of the carrier-grade Linux operating system. Linux is known for high availability and performance, and nowadays is the preferred operating system for mission-critical communication networks.

The AdvancedTCA platform (see picture above) is the designated hardware option for building large TetraNode networks. AdvancedTCA (Advanced Telecommunications Computing Architecture) is targeted primarily to the requirements for "carrier grade" communications equipment and is an open-standards based platform, offering processor blades, IP switching blades and supervisory modules with the highest level of performance and reliability in the computer industry.

2.2 Base Station System

The TETRA **Base Station Systems** (BSS) are connected by IP to the TNX. The Ethernet based IP links allow easy integration with either shared or dedicated IP backhaul links. The Base Station System comes in a pre-configured cabinet for either two (BSS2) or four (BSS4) carriers. Four cabinets can be combined to a maximum of 16 carriers at one single site.

Optionally the Base Station System can be connected to a GPS antenna for precise time synchronisation. This enables Type 1 and 2 cell reselection for seamless handover. Even without GPS synchronization available, the base stations are still able to continue operation within its timing specifications for a period of 10 years. Alternatively the Base Station System supports the Precision Time Protocol (PTP) on basis of IEEE1588v2, an option for TETRA networks in which GPS is either not trusted or practically not available, like in underground or in-building coverage.

3 Principle of Operation

The ever-evolving computing performance of standard IT technology has enabled the development of the soft switch based TetraNode technology. While software on top of COTS server hardware is used to perform all processing, switching and routing of TETRA speech and data, proprietary circuit switch hardware and proprietary IP-based router equipment are no longer needed.

The TNX soft switch covers the following subsystems:

- Call and resource management;
- TETRA protocol stacks;
- Switching and routing of TETRA voice, SDS, status and packet data calls;
- Gateways to dispatch, telephony and application servers;
- Database and network management.

The integrated soft switch solution eliminates the need for multiple physical servers or hardware virtualization, resulting in lower configuration and maintenance complexity.

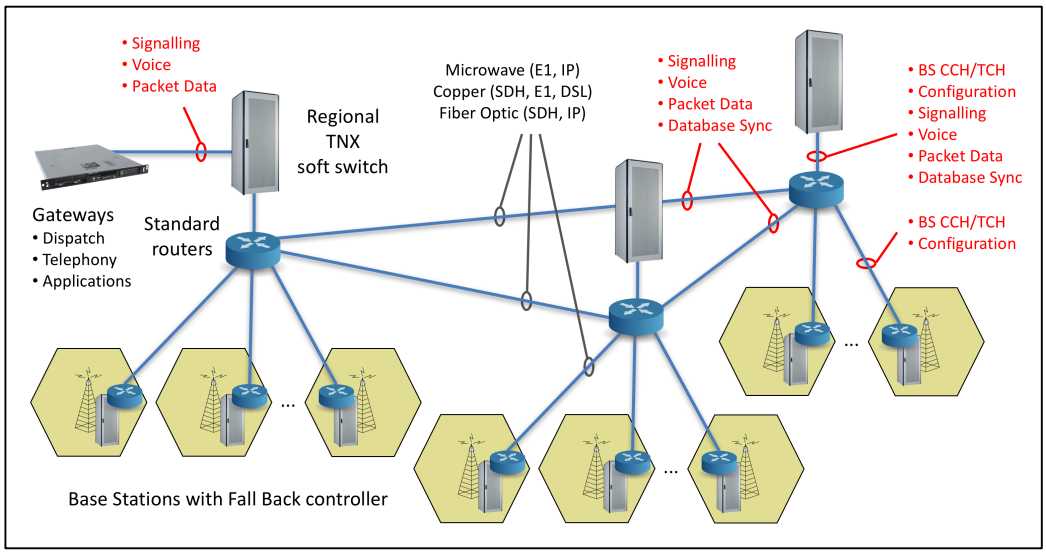

Figure 2 – Multi-node TetraNode network

The TNX soft switch architecture supports multi-vendor, open-standards based IP routers. Standard UDP/IP and TCP/IP, as well as IP Unicast and Multicast routing protocols are used to establish and maintain connections, to transfer speech and data, and to provide management functions. Depending on the requirements for availability, a selection can be made from enterprise-grade COTS router equipment that support the OSPF protocol, or carrier-grade MPLS-enabled routers to achieve the highest level of availability.

Equipment redundancy is achieved by duplicating the TNX soft switch, either on a single location by means of co-located redundant hardware, or on a physically different location, providing geographic redundancy.

For maximum availability, redundant links should be considered from the main and redundant TNX soft switch to each of the base stations. Since no IP multicast is used in between the TNX soft switch and the base station, and configuration of the base stations is performed on the TNX soft switches only, the configuration complexity is significantly reduced.

A single TNX soft switch offers sufficient capacity to serve a large city or region where most of the communication is concentrated. The inter-TNX links carry the signalling, voice and data, and database synchronisation messages, allowing transparent operation of functionality over the entire network. The inter-node network topology can also include redundant links between TNXs to achieve higher network availability.

This combination of high-capacity TNX and multi-node capability offers the best in terms of performance and limitation of link bandwidth. Typically 80 to 90% of the communication is kept locally, resulting in the lowest possible call setup delays, regardless of the number of base stations involved in the call. The remaining 10 to 20% is routed to other TNX's, for which a modest call setup delay is added, but with the benefit of lower inter-TNX link bandwidth and no need to connect base stations over dedicated long distance links.

Regarding scalability, the TNX soft switching architecture offers a capacity and performance similar to that of hierarchical proprietary IP based networks. At the same time, it requires less hardware equipment, involves virtually no legacy / component obsolescence issues, it offers simpler redundancy concepts, and is (much) easier to configure and troubleshoot. This results in higher availability and lower investment, implementation and operating costs.

More information on the benefits and limitations of different TETRA network architectures can be found in the white paper "Reliable and Scalable TETRA networks" that can be downloaded from the Rohill web site.

4 Network scalability

System scalability is an important aspect for mid-size and large TETRA networks for Public Safety. Scalability is measured by a wide variety of metrics, that include the number of supported base stations, number of carriers, number of dispatch stations and interconnection with other networks, like telephony and adjacent TETRA or conventional radio networks serving other Public Safety regions.

TetraNode is highly scalable by offering a mix of multi-site and multi-node configurations.

4.1 Multi-site scalability

Multi-site is the preferred approach for high-density TETRA networks in urban areas, whereby a high load is expected for voice and data communications within a limited geographic area. Examples are TetraNode networks that cover a large city, or a region with multiple cities.

The current generation of AdvancedTCA processor blades allow support for up to 120 base station sites and 384 TETRA base station carriers. This results in a maximum of 384 x 4 = 1.536 channels that can be used in control, voice and packet data mode. In addition, 512 channels are available for dispatch, telephony and inter-TNX communication. Note that the TetraNode Dispatch Server allows for additional scalability by allowing multiple dispatchers to use the same channel for group calls in which multiple operators participate.

To illustrate this scalability, four typical examples are provided for calculation of capacity on basis of TetraNode multi-site scalability:

Description	Small city or region	Medium city or region	Large city or region	Very large city or reg.
Number of Base Station Sites	5	20	60	120
- BSS with 6 carriers	0	0	0	5
- BSS with 5 carriers	0	0	5	10
- BSS with 4 carriers	1	3	10	15
- BSS with 3 carriers	2	7	20	30
- BSS with 2 carriers	2	10	25	60
Number of channels for BSS [1]	56	212	700	1.400
Number of dispatch stations [2]	8	20	40	80
- Number of separate / common groups [3]	42	40	70	100
Number of telephony channels	15	30	45	60
TOTAL number of channels	**118**	**302**	**855**	**1.640**
Percentage of TNX capacity	**6%**	**16%**	**42%**	**80%**

Table 1 – TetraNode capacity calculation

Notes:

1. Each TETRA carrier requires 4 channel capacity for either control, traffic or packet data;
2. Every dispach station also accounts for one individual call;
3. For the Small city scenario no TDS is assumed (less than 16 dispatch stations) for which every group on each dispatcher requires a separate channel, whereas for the other two scenarios with TDS the number represents the number of shared channels.

The network loading is limited by the channel capacity. In reality, the loading is highly dependent on the time of day (busy hour) and the occurrence of incidents.

For calculation of the maximum (peak) network load in which also a few incidents are handled requiring maximum capacity of several sites, it is assumed that 70% of the capacity is used for group calls with an average propagation of 5 sites for a group and an addition 7% of the capacity is used for individual calls. The remaining capacity is used for control channels and idle capacity.

Description	Small city or region	Medium city or region	Large city or region	Very large city or reg.
TETRA channel capacity	56	212	700	1.400
- Control channels (approx. 8%)	5	20	60	120
- Group calls (70%)	39	148	490	980
- Individual calls (7%)	4	15	49	98
- Remaining capacity (approx. 15%)	8	29	101	202
Number of group calls	8	30	98	196
Number of individual calls	4	15	49	98
Maximum expected number of calls	**12**	**45**	**147**	**294**

Table 2 – TetraNode single-node load calculation

4.2 Multi-node scalability

Large nationwide networks can be built by using TetraNode multi-node, whereby different regions and cities are covered with seamlessly operating voice and data services.

The expandability of TetraNode multi-node is virtually unlimited in terms of supported number of base stations sites, carriers, dispatch stations, system interconnect and telephony gateways. Although voice and data services are handled transparently within a multi-node network, it is important to prevent unnecessary inter-TNX communication to avoid the extra inter-TNX link capacity and -delay. The following best practices can be applied:

- A single node can provide coverage for any size of city in which most of the communication (approx. 80%) is handled locally;
- A single node can also cover several cities and villages in a region;
- Group call propagation may be limited to a single node when these groups are never used outside the city or region.

The following table shows a typical multi-node network scalability calculation for a total of 600 sites:

- One node according the "Very large city or region" specification with 120 site coverage;
- Six nodes according the "Large city or region" specification with 6 x 60 = 360 site coverage;
- Six nodes according the "Medium city or region" specification with 6 x 20 = 120 site coverage.

Description	Medium city or region	Large city or region	Very large city or reg.	TOTAL
Number of nodes	6	6	1	13
Number of sites per node	20	60	120	
Total number of sites	120	360	120	600
Maximum expected calls per node	45	147	294	
Total number of calls	**270**	**882**	**294**	**1.446**
Number of inter-TNX calls per node	9	29	59	
Total number of inter-TNX calls	**54**	**174**	**59**	**287**

Table 3 – TetraNode multi-node load calculation

5 Performance

TETRA networks for Public Safety require fast, reliable and efficient methods to carry application-specific status and data packets. These packets need to be interleaved with voice calls, making the TETRA status and Short Data Service (SDS) functionality the appropriate choice.

TetraNode offers very high performance and capacity (throughput) levels for both voice and data calls. These performance and capacity levels are consistently provided as proven by many Public Safety and Public Transport projects:

- Transfer of more than 2,5 million Short Data Service (SDS) messages per day in a 10-sites TETRA network for bus location tracking, and providing information to bus passengers and signage displays near bus stops.
- Polling rate of 500 ms (twice per second) for each train for location tracking and availability checks to guarantee safety critical operations.
- Location reporting of up to 1000 vehicles with a reporting interval of 10 seconds served by a single TETRA base station.
- Consistent 195 ms voice call setup and SDS / status transfer period.

These outstanding performance levels are enabled by the following TetraNode capabilities:

- Highly responsive call manager for voice and data calls;
- Efficient encoding (so-called association and fragmentation) of TETRA signalling and data over the air;
- Support of up to three Secondary Control Channels (SCCHs) in addition to the Main Control Channel (MCCH), configurable on a per-site basis;
- TetraNode IP Gateway (TIG) that serves as an efficient Application Programming Interface (API) for both voice and data applications, supporting simultaneous voice and data calls.

For multi-node operation, the inter-TNX voice call setup becomes 195 + 90 = 285 ms, which is within the 300 ms call setup period requirement for mission-critical TETRA networks.

6 Validation of network scalability and performance

Mitigation of risks is the most important consideration for rolling out and upgrading TETRA networks. New software features and enhancements, as well as variation in network topologies and configuration, introduce risks that are inevitable and need to be managed to ensure that communications are not disturbed.

Like most other TETRA network suppliers, Rohill has built its own load and stress test environment using a significant amount of base stations and mobile stations to perform pre-testing of software releases. This load and stress test environment consists of three sites with eight carriers (TETRA frequencies), whereby approximately eighty TETRA radios are controlled by five rack-mount servers with software for execution of PTT operated group calls as well as text, status and GPS messaging.

The size of this load and stress test system is by far not enough to conclude the effects of load on real networks that are in operation today. But even with this limited capacity, we already faced issues like limited flexibility and low reliability for executing scenario testing, and high running cost because of maintenance, depreciation and high power consumption.

To overcome this limitation in an energy-efficient and cost effective way and to deliver proof of our capabilities in validating and delivering large TETRA networks, Rohill decided to invest in the development of a pure software based solution for large-scale emulation of TETRA base stations and mobile stations.

6.1 TNX-SIM solution

To validate the performance and reliability of the TetraNode solution, Rohill has developed the highly scalable TetraNode Simulation (TNX-SIM).

The hardware of the TNX-SIM consists of the same Commercial Off The Shelf servers as deployed all over the world. Software running on these servers precisely emulate the Rohill base station carriers, as well as large numbers of mobile station instances. These mobile stations are scripted to generate numerous voice and data calls. In addition, the scripts trigger mobility events, like registration, group attachments and cell reselection (roaming and handover).

The TetraNode Core system does not observe any difference in behaviour of TNX-SIM compared to real TetraNode Base Station Systems (BSSs) and generic TETRA radios.

A single TNX-SIM server supports up to 50 sites, 100 carriers and 5.000 radios, whereby the load can be scaled up to 70.000 voice calls, 300.000 SDS messages and 100.000 packet data messages per hour. The load capacity increases linear with the number of TNX-SIM servers.

Description	Standard load test	Single TNX-SIM	Current TNX-SIM
Number of (simulated) TETRA base station sites	3	50	400
Number of (simulated) TETRA base station carriers	8	100	800
Number of (simulated) TETRA radios	80	5.000	40.000
Number of servers for load test or TNX-SIM	5	1	8
Number of voice calls per hour	5.000	70.000	560.000
Number of SDS messages per hour	20.000	300.000	2.400.000
Number of packet data messages per hour	8.000	100.000	800.000
Number of simultaneous voice calls	20	200	1600
Number of simultaneous packet data calls	5	50	400

Table 4 – TNX-SIM load capacity

6.2 Test scenarios

The TNX-SIM simulates all generic call types that are relevant for any TETRA network. These call types include registrations, call restoration (roaming, handover), PTT operated group calls, SDS, status, GPS messaging and packet data.

The available call types can be triggered automatically on basis of scripts that specify the number of calls spread over certain periods of time with a fixed or random interval. This allows precise emulation of peak load during the busy hour, a disaster scenario whereby a very large number of radios are operating in a small geographic area, and a migration scenario whereby many registrations are received in a short period after activating the new TETRA network.

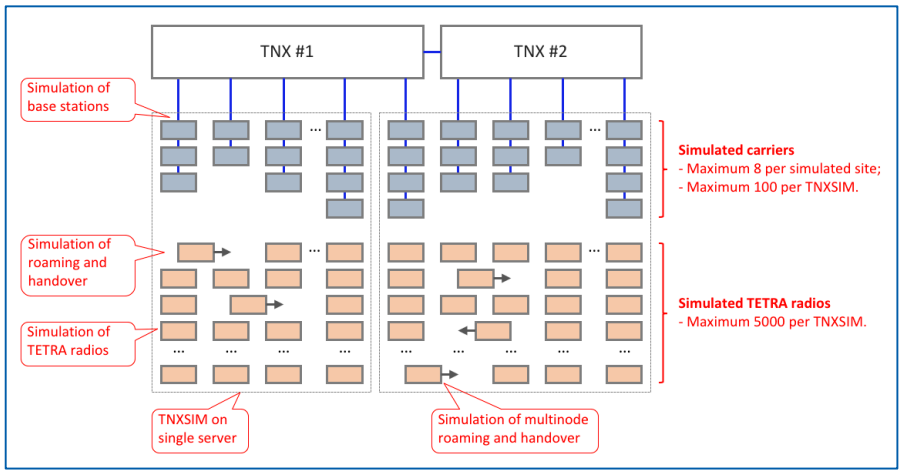

Figure 3 – TNX-SIM environment

During and after the validation period, the call performance, availability and CPU load of all TNXs in the network are verified in order to check both peak and long-term performance and stability.