Implementation of Order-wire Functionality in IRITEL NG-SDH devices

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Abstract—**This paper describes the implementation of order-wire functionality in NG-SDH devices ODS2G5 and OTS622 IRITEL. The paper also describes the operation of order-wire in networks with arbitrary topologies, as well as the configuration of order-wire functionality by using network management software SUNCE. The presented solution for order-wire functionality is compared with VoIP solutions. The paper shows that the presented solution provides fast reaction to network failures, while keeping the implementation simple.**

Keywords — **NG-SDH, order-wire, VoIP, network management, reliability.**

I. INTRODUCTION

ORDER-WIRE is a voice communication channel within a telecommunication network reserved for use by network administration and maintenance personnel. By using order-wire, personnel can communicate in a simple and reliable way, usually by using a phone which is connected to a telecommunication device. The phone uses a reserved channel for communication with a phone connected to another device in the network. Order-wire functionality is important because it enables personnel located in network stations to communicate using established communication channels, not requiring the existence of a separate telecommunication network.

SDH standard defines bytes for transmission of order-wire signals in the overheads of regenerator and multiplex sections [1]. Byte E1 of SDH regenerator section overhead and byte E2 of multiplex section overhead are reserved for order-wire. Byte F1, located in regenerator section and reserved for use by network personnel, can also be used for order-wire. SDH frames are transmitted at a constant speed of 8000 frames per second, and hence every byte used for order-wire generates a 64kbit/s channel, which can carry a PCM [2] voice signal.

The second section of this paper describes the design of order-wire functionality within ODS2G5 and OTS622 IRITEL [3]-[4]. Transmission of order-wire signals and network operation of order-wire are described in the third section. The fourth section describes the configuration of order-wire functionality through the use of SUNCE [5], the network management software for IRITEL telecommunication devices. Latency of voice signals during order-wire communication is analyzed in the fifth section. The sixth section compares the order-wire solution described in this paper with solutions that use one of the VoIP standards [6]-[7]. The conclusion is presented in the seventh section.

II. ORDER-WIRE FUNCTIONALITY OF ODS2G5 AND OTS2G5 IRITEL DEVICES

Fig. 1 depicts a modular schematic of order-wire functionality in ODS2G5 and OTS622 IRITEL NG-SDH telecommunication devices.
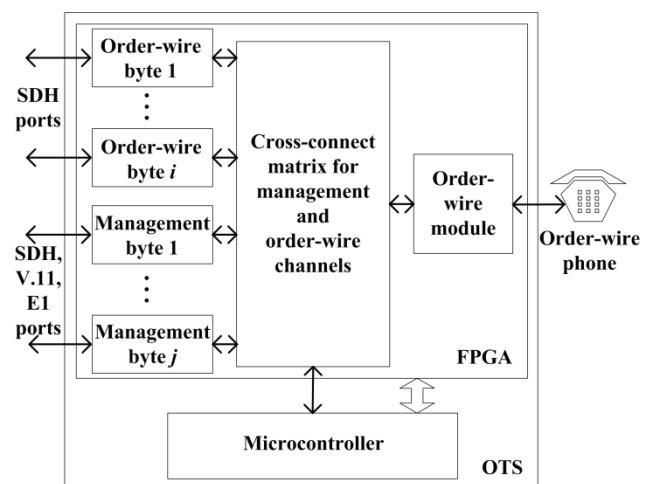

Fig. 1. Order-wire functionality of ODS2G5 and OTS622 IRITEL devices.

An order-wire phone is a standard phone which can be connected to an order-wire module using a RJ11 connector. The order-wire module implements the SLIC functionality towards the phone, with tone dialing supported.

The order-wire module enables the configuration of device's phone number, which can have between one and three digits. The phone number is configured using SUNCE management software. Besides conversations between two parties, order-wire module also enables conference calls, which can include any phone in order-wire network by using the dedicated phone number 00. Order-wire module has built-in protection from channel blocking, ensuring connection termination after a predefined period of inactivity in cases when a telephone is accidentally left off-hook after a conversation.

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The central part of Fig. 1 contains the cross-connect matrix for management and order-wire channels. This matrix can forward bytes of order-wire channels between order-wire modules and any SDH port of the device. It can also forward bytes of order-wire channels directly between SDH ports, a feature required for the proper functioning of order-wire, which will be described in the following sections. The cross-connect matrix can also forward management bytes between a microcontroller and any port of the device that can carry management bytes (SDH, V-11 or dedicated E1 management ports), or between any two ports which can carry management bytes.

Order-wire module and cross-connect matrix for management and order-wire channels are implemented in FPGA chip and are configured by the microcontroller. FPGA chip and the microcontroller are both located on OTS unit of ODS2G5 and OTS622 IRITEL devices. The microcontroller communicates with SUNCE management software and receives configuration changes from it.

III. ORDER-WIRE FUNCTIONALITY IN NETWORK OF ARBITRARY TOPOLOGY

A. Linear Topology Network

Fig. 2 depicts order-wire configuration in networks of different topologies. The figure shows SDH devices as circles. Inside the circles, arrows depict the forwarding directions of order-wire bytes through cross-connect matrix described in the previous section. Cross-connect matrices are configured so that order-wire modules belonging to different devices are connected, forming a closed unidirectional path. This enables establishment of order-wire calls between any two devices in the network, or establishment of a conference call. Since order-wire paths are unidirectional, during a conversation between two parties each direction takes up one part of the closed order-wire path. Fig. 2a shows an order-wire path for a linear topology network.

In the case of a network element failure, that network element is automatically excluded from the order-wire path. Fig. 2b illustrates the case of link failure in a linear topology network. After the link between devices B and C is broken, the network is divided into two separated networks, and new order-wire paths are established within these networks. New order-wire paths enable calls within newly created networks.

Any subsequent failure in one of the new networks would further divide that network. After a failure is removed, two networks it separated are joined again, and the order-wire path is automatically restored, connecting all devices in the joined network. Both reaction to the failure by exclusion of the failed network element and restoration of order wire path after the failure is repaired, are performed locally, using alarms detected in devices closest to the failure, which results in very short recovery times.

B. Ring Topology Network

If a network topology contains a ring, then the order-wire channels in the network will be grouped into two closed order-wire paths, as presented in Fig. 2c. The order-wire path added through the introduction of the ring is labeled as a backup path in Fig. 2c. While there are no failures in the ring, this path doesn't carry order-wire signals. Should a failure in the ring occur, the backup path would carry an order-wire signal.

a) Order-wire path in linear topology network

b) Link failure in linear topology network

c) Order-wire path in ring topology network   *d) Link failure in ring topology network*

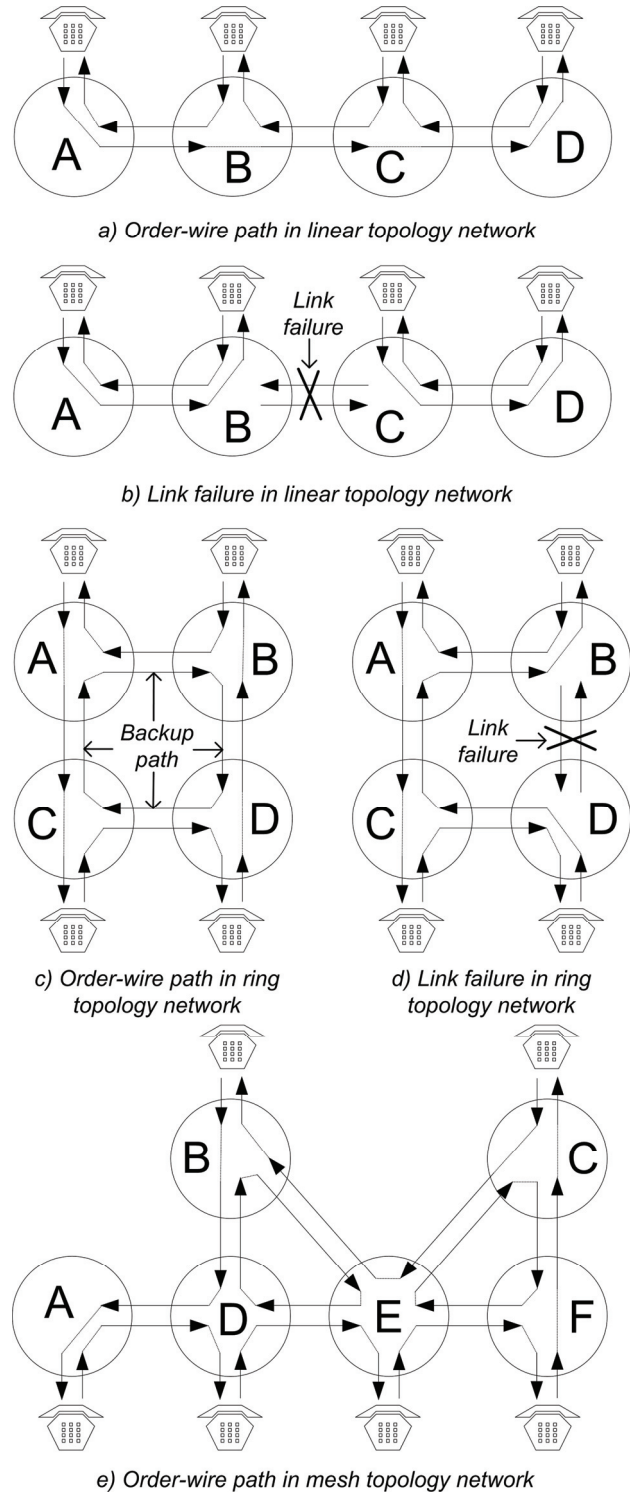
e) Order-wire path in mesh topology network

Fig. 2. Operation of order-wire in networks.

On the devices adjacent to a failed network element, order-wire path reconfiguration is performed so that failed ring traffic directed towards failure is sent into a backup path of the ring. Also, the order-wire channel that was receiving traffic from a failed direction is switched to receive traffic from the backup path. As a result, the failed part of the ring is replaced by the backup path. In the case of multiple failures in the ring, this procedure will result in functioning order-wire path through parts of the ring not affected by failures.

In the example of the failure presented in Fig. 2d, the failed link between devices B and D is automatically excluded from the order-wire path, by performing a local action in devices B and D. A newly created order-wire path still encompasses order-wire modules of all devices in the network and enables conversation of network personnel between any two or more telecommunication stations.

C. Mesh Topology Network

In the case of a mesh topology network a closed, unidirectional order-wire path is created, connecting all order-wire modules (Fig. 2e), just as it is done with linear and ring network topologies. In the process of path creation, backup paths should be created within the network rings. A procedure for finding rings in a mesh network and configuration of order-wire path by using SUNCE software is described in section IV.

D. Order-wire Conference Call

Besides conversations between any two parties in the network, order-wire functionality includes conference calls, in which any number of parties can join or leave the call. A conference call is initiated by the calling party dialing 00. After that, all phones in the network ring and other parties can join the call at any time.

E. Order-wire reliability

In the case of SDH link failure, that link would be excluded from the order-wire path, and in the case of a device failure, that device and all links connected to that device would be excluded from the order-wire path. The removal of links from order wire path is performed automatically, after the detection of a link failure or reception of link failure information from a neighboring device. After the reconfiguration is performed, the order-wire will use all functioning links in the network and provide the connectivity between order-wire modules of devices, as long as there is at least one functioning path between those devices. The removal of a broken link from the order-wire path is performed very quickly because this action is performed locally in the device, immediately after detection of a failure. This feature fulfills strict requirements for service availability.

IV. ORDER-WIRE CONFIGURATION USING SUNCE SOFTWARE

SUNCE is the network management software for networks of IRITEL devices. Order-wire configuration form is located in SUNCE module for management of NG-SDH devices ODS2G5 and OTS622. Fig. 3 depicts SUNCE order-wire configuration form.

The configuration of all SDH ports is presented in the table shown in Fig. 3. In order to change the order-wire configuration of a SDH port, the operator can select a table row assigned to that port, and use the controls located above the table to perform the configuration. It is possible to configure whether an SDH port is included in an order-wire path, which overhead byte of SDH frame is used to carry order-wire signal (E1, F1 or E2). It is also possible to configure whether the port belongs to a ring, and, if the port belongs to a ring, the values of port's ring parameters can be configured.

The configuration of order-wire rings implies the specification of pairs of ports belonging to a ring and the direction of order-wire path through a ring. The pairs of ports belonging to a ring are configured using the last two columns of the table depicted in Fig.3. For every port belonging to a ring, it is possible to define to which other port of the same device it is connected in a ring. By using the button labeled "Configure Peer" software can, based on the configuration of one device's port belonging to a ring, automatically configure the other port.

Interface	Active	Overhead byte	Ring	Protection	Input	Connected to board	Connected to interface
P#01 SDH#1 (OTS)	Yes	E1	No	Yes	No	1	1
P#01 SDH#2 (OTS)	Yes	E1	No	Yes	No	1	2
N/A	No	E1	No	Yes	No	1	3
N/A	No	E1	No	Yes	No	1	4
P#02 SDH#1 (S4ADM)	No	E1	No	Yes	No	2	1
P#02 SDH#2 (S4ADM)	No	E1	No	Yes	No	2	2
N/A	No	E1	No	Yes	No	2	3
N/A	No	E1	No	Yes	No	2	4
P#03 SDH#1 (S4LI)	No	E1	No	Yes	No	3	1
P#03 SDH#2 (S4LI)	No	E1	No	Yes	No	3	2
P#03 SDH#3 (S4LI)	No	E1	No	Yes	No	3	3
P#03 SDH#4 (S4LI)	No	E1	No	Yes	No	3	4
P#04 SDH#1 (S4LI)	No	E1	No	Yes	No	4	1
P#04 SDH#2 (S4LI)	No	E1	No	Yes	No	4	2
P#04 SDH#3 (S4LI)	No	E1	No	Yes	No	4	3
P#04 SDH#4 (S4LI)	No	E1	No	Yes	No	4	4
P#05 SDH#1 (S4LI)	No	E1	No	Yes	No	5	1
P#05 SDH#2 (S4LI)	No	E1	No	Yes	No	5	2
P#05 SDH#3 (S4LI)	No	E1	No	Yes	No	5	3
P#05 SDH#4 (S4LI)	No	E1	No	Yes	No	5	4
P#06 SDH#1 (S4ADM)	No	E1	No	Yes	No	6	1
P#06 SDH#2 (S4ADM)	No	E1	No	Yes	No	6	2
N/A	No	E1	No	Yes	No	6	3
N/A	No	E1	No	Yes	No	6	4

Fig. 3. Order-wire configuration form for ODS2G5 and OTS622 IRITEL devices.

In order to configure the direction of order-wire path, the operator can choose the direction of ring traversal and, for each device, mark the device's port which is encountered during traversal as input port, and port on which a signal exits the device as output port. Based on the information on which port in the ring is input and which is output, software can properly configure an order-wire path and backup order-wire path in the ring. One device can be configured to participate in multiple order-wire rings.
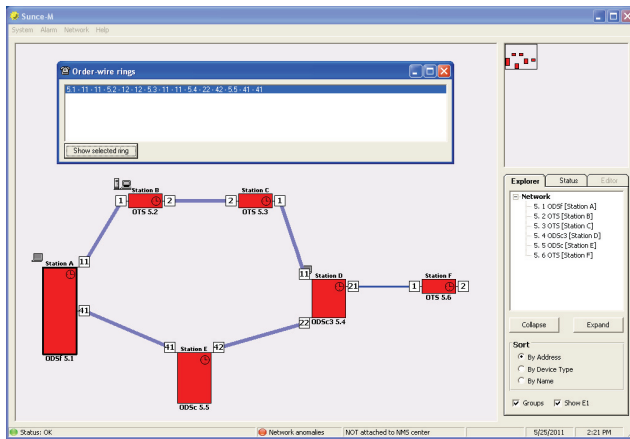
Fig. 4. Order-wire rings form and presentation of selected ring on network form of SUNCE software.

The task of finding rings available in the network can also be performed by SUNCE software. Form for the ring discovery is part of the network management layer of SUNCE software. Fig. 4 presents a ring discovery form and network form of SUNCE software. On the topology view, lighter and thicker lines represent links that are included in the currently selected ring on the ring discovery form. On the form with a simple topology presented in Fig. 4 only one ring exists, and only a SDH link that doesn't belong to that ring is located in the right part of the network. In the case of more complex network topologies, a ring discovery form would present a set of rings.

The configuration of order-wire phone number is performed on another form of SUNCE software.

V. Signal Delay in Order-wire Path

Order-wire traversal through all nodes in the network raises the question of signal delay caused by accumulated propagation times through links and devices in the network.

The delay of order-wire signal through device in the case when a phone is involved in conversation, t_a, amounts to 375μs, and it is t_b = 250μs if the signal only traverses the device. In the example, we will assume that links are 100km long, so that an optical signal needs approximately t_c = 500μs to travel through a link. The number of network nodes and the total length of links depend on network topology and number of order-wire rings in the network. In a network without rings, n devices and n-1 links would exist. The longest total delay in order-wire path t_u occurs when all devices take part in a conference call, because in that case the delay through each device is the longest and is equal to t_a. The order-wire signal traverses all devices 2·(n-1) times. Of that total number, when all devices are included in the conference call, n traversals through device include the order-wire module and n-2 don't. A signal also traverses every link twice and the maximal total delay in an order wire path amounts to:

$$t_u = t_a \cdot n + t_b \cdot (n\text{-}2) + 2 \cdot t_c \cdot (n\text{-}1). \qquad (1)$$

In the case when an allowed signal delay has to be less than 250ms, using (1) we find that the network can contain at most 154 devices. In a network topology that contains rings, in case when there are no failures in the network, an order-wire path would not be longer, because order-wire signals traverse ring links only in one direction (Fig. 2). In the case of ring failures, the problem is reduced to the previously analyzed case of network with no rings.

VI. Comparison with the VoIP Solution

A SDH network contains an embedded management network. This is a packet network, and its channels are part of SDH overhead. In this network, voice communication can be established using VoIP. Call control protocols, such as H.323 [6] and SIP [7], can establish a direct connection between any devices. Dynamic routing protocols such as OSPF can enable connectivity between two devices as long as there is at least one path, and thus enable establishment of VoIP calls.

The advantage of order-wire solution is the speed of reconfiguration when a failure occurs: reconfiguration is performed locally, in the devices that detected the failure. On the other hand, for reconfiguration in packet network, routers need to exchange information about topology changes, and a convergence time can be significantly longer than the time of reconfiguration of the order-wire path.

The use of VoIP order-wire enables a number of simultaneous conversations in a network, while the proposed solution enables only one conversation between two participants or one conference call in a network at one point in time. For VoIP, the maximal number of simultaneous order-wire conversations is determined by the capacity of management channel in SDH overhead. According to SDH standards, it is possible to use bytes D1-D3 of regenerator section overhead and bytes D4-D12 of multiplex section overhead. When all these bytes are used, the capacity of management channel amounts to 768kbit/s. If bytes E1, F1 and E2 would be included in management channel, the capacity of management channel would be increased by 192*kbit/s*. When VoIP order-wire is used, it is important to provide guarantees that VoIP traffic does not affect other traffic in the management network, which includes information needed to manage devices in SDH network such as alarms sent from devices towards a network management center, configuration and performance information.

Forwarding of packets in a management network is usually performed by a microprocessor, which should be taken into account when calculating a processor load. Processing and forwarding of IP packets, as well as VoIP call control and speech transmission protocols are more complex than the formation of order-wire path, so they have a greater probability of errors. Complexity of the VoIP order-wire solution is additionally increased because it depends on other components of the system, such as software that executes dynamic routing protocols in a management network.

VII. Conclusion

Order-wire implementation of ODS2G5 and OTS622 IRITEL is based on the use of order-wire path which encompasses all devices in the network. This solution enables localized and fast reaction to failures. Also, the presented solution has a simple implementation, which introduces a smaller probability of errors in the implementation, and also saves processing resources of the device. Fast reaction to failures and increased reliability of the system are important features in a high reliability transport network.

Acknowledgement

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