RFID Applied to Optical Spectrum for Network Resources Inventory Management

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Abstract

In this work a new management model and capacity evaluation of a Telecommunication Network will be proposed by using RFID, a technology globally employed in logistics and supply chain control. This implementation will be achieved by introducing a binary combination of RF subcarriers in the optical spectrum through optical modulators. This new arrangement will establish a new management model - distributed, real-time, and reliable; for inventory evaluation in Telecom Optical Networks.

Keywords-RFID; network management; WDM optical networks; NGN; inventory evaluation management

1. Introduction

Since the mid 90's, a new generation of networks based on DWDM/IP/GBEthernet/XDSL came to the market [1] [2]. Because each technology was built as an independent one, their management was implemented using legacy multiplatform systems. Despite recent research and development efforts, network management remains a key challenge for network operators [3].

Instead of implementing the traditional RFID (Radio Frequency Identification) using wireless communication between tags and readers, in the present paper a new idea is being proposed where RFID patterns will be written and read inside optical fibers. This new arrangement will establish a new management model - distributed, real-time, and reliable; for inventory evaluation in Telecom Optical Networks. This paper will be organized as follows.

In section 2 a description of the proposed system will be presented. In section 3 it will be shown how the above-mentioned RFID label may be easily introduced in the optical spectrum. In section 4 it will be shown how these RF (Radio Frequency) subcarriers, together with intelligence introduced in the physical layer, will work towards providing a new management model. The final comments, conclusion and future works will be presented in section 5.

2. Description of the proposed system

Aiming to achieve this new model, a device able to work as a low level interface, coupled to a telecom network element (NE) will be presented. The main task of this device will be the introduction of electrical RF subcarriers inside WDM [4] [5] metropolitan optical rings. Each node of the ring will be associated to a unique master RF subcarrier located in the microwave domain as illustrated in Fig. 1.

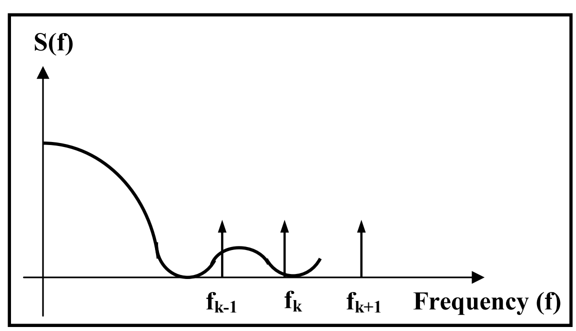

Figure 1. Master RF subcarrier for nodes k-1, k, and k+1

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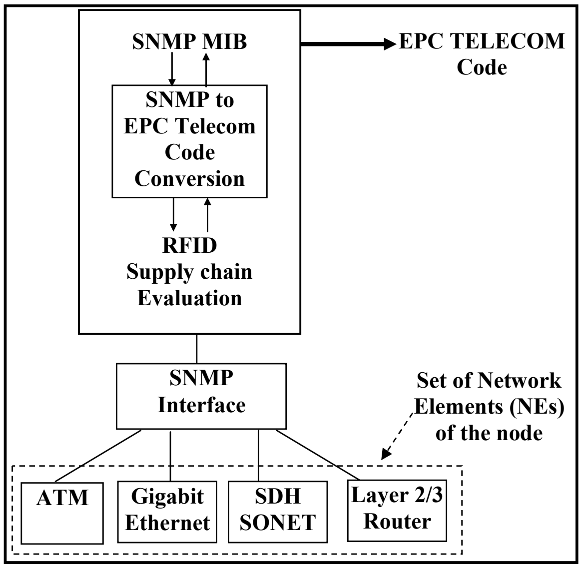

Figure 2. Local node with SNMP supervision and EPC Telecom generation

Fig. 2 illustrates how a SNMP (Simple Network Management Protocol) interface could produce a MIB (Management Information Base) indicating the inventory capacity status of the node. Then, each network element will be associated with a unique identification (ID) code like an Electronic Product Code (EPC) [6] used in the RFID system, adapted for a Telecom network – here named EPC Telecom.

The node status information in EPC Telecom will be processed in a DSP/FPGA [7][8][9][10] board to generate an RF subcarrier array spectrum in low frequency domain. The array of RF subcarriers is associated with a binary code where the subcarrier presence indicates a bit "1" and its absence represents a bit "0" – Fig. 3. This spectrum will be up-converted by the master subcarrier of the node – Fig. 4 [11].

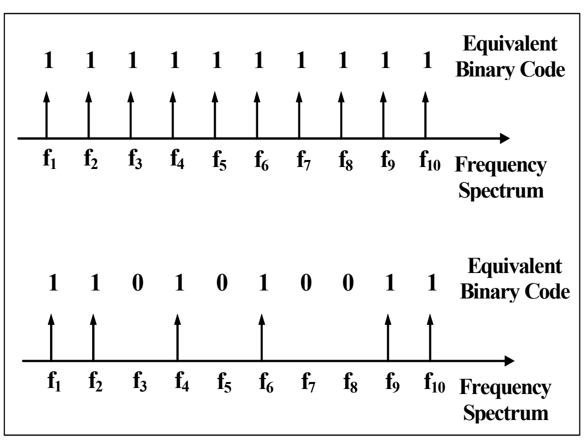

Figure 3. Binary code and subcarrier addressing

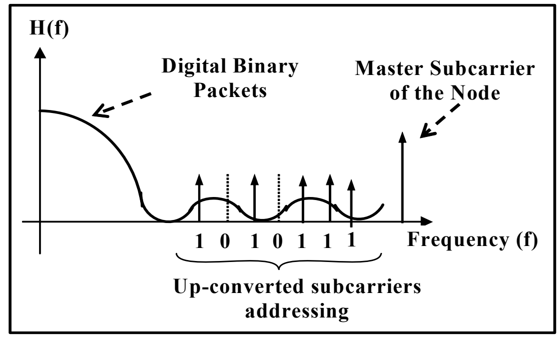

Figure 4. Data and RFID spectrum up-converted over the master subcarrier of the node

3. RF Subcarrier into optical domain

Similar to RFID traditional systems – where labels answer the queries from reader transmitting a modulated signal back [6] –, here one node, comprising a set of Network Elements (NEs), receives information from all others nodes, and introduce the information from its own set of NEs inside the optical domain. The block diagram in Fig. 5 represents the transmission process of a generic node, whilst Fig. 7 depicts the reception process.

In Fig. 5, assuming that a specific data package will aggregate the RFID information field, when a NE launches a data package (A), an associated microwave tone, named master subcarrier, will be electrically generated (B).

This master subcarrier will up-convert the RF subcarrier array – named EPC Telecom, that contains the inventory status information of the node (C). The resulting signal is then introduced into the optical domain through a Mach-Zendher or an eletroabsortion modulator (D). The RF master subcarrier frequency should be above the higher significant frequency of the data spectrum, in order to avoid detection error [12].

Each node will have a SNMP [13] management to query the NEs. The status of NE is loaded in a buffer unit (E). This unit interfaces with an Intelligent DSP / FPGA board [10]. Due to a non disclosure agreement involved, some circuit details and considerations will be omitted. The information in the buffer – usually loaded in the ASCII format – to be transmitted, is then converted to EPC Telecom – the EPC code adapted to Telecom Networks. The processing stage in the board implements a subcarrier array with 32 tones over the master subcarrier. Each node will have your own master subcarrier associated with its EPC Telecom array between 1 – 30 MHz.

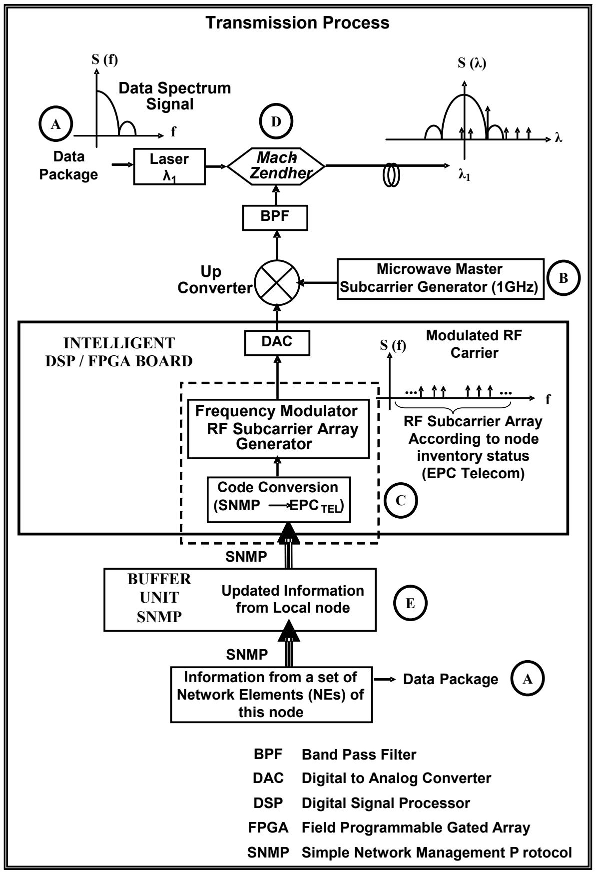

Figure 5. Block diagram of a generic optical network node using RF subcarrier array code inside optical domain – Transmission Process

Since an array of RF subcarriers may be associated with data packages in optical domain, and the RFID logistics is already a mature technology, the evaluation of the network status may be implemented by an ultra-fast processing of the RF domain extracted from optics.

Once the package has the payload and its EPC Telecom code added, a frequency spectrum according to Fig. 6 will be observed. For each node, an EPC Telecom code will be added over its own master subcarrier. After the first loop collecting information in an optical ring, a complete status of the network could be obtained through the set of master subcarriers and their respective EPC Telecom array.

At the receiving side of each node, represented by Fig. 7, the first step will be the down conversion of each master subcarrier (F), aiming to implement the RFID/EPC Telecom processing in a lower frequency range. Each EPC Telecom array will be extracted from their respectively master subcarrier and code converted (G). Then, all the updated income information from others nodes of the network will feed the buffer unit (H). Again, DSP and FPGA circuitry intelligence is generated to implement this step (I).

Transmission and reception sides of each node will then interact to keep network inventory information active and updated – Fig. 8.

4. New management approach using RFID/EPC Telecom

As telecommunications network management become more complex by using new NGN (Next Generation Network) and legacy technologies, traditional approaches based in human monitoring results in a less reliable performance.

RFID technology could be associated with the subcarrier addressing to implement a new intelligent physical layer. This procedure generates, as mentioned before, a new kind of low level device configuration process. These intelligent low level devices could enable different program models used by NGN and legacy resources to supervise the network through faster and simpler procedure. Learn and reasoning and Ontological comparisons [14] could become much more economic and efficient. The basis of this approach is the application of EPCglobal [6].

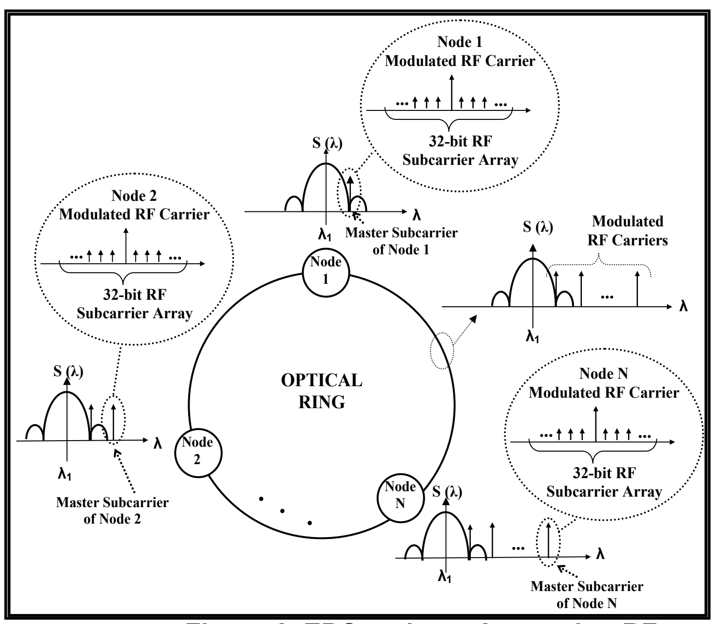

Figure 6. EPC code analogy using RF subcarriers inside optical domain. Each master subcarrier associated to each node is modulated with a 32-RF-sucarrier array

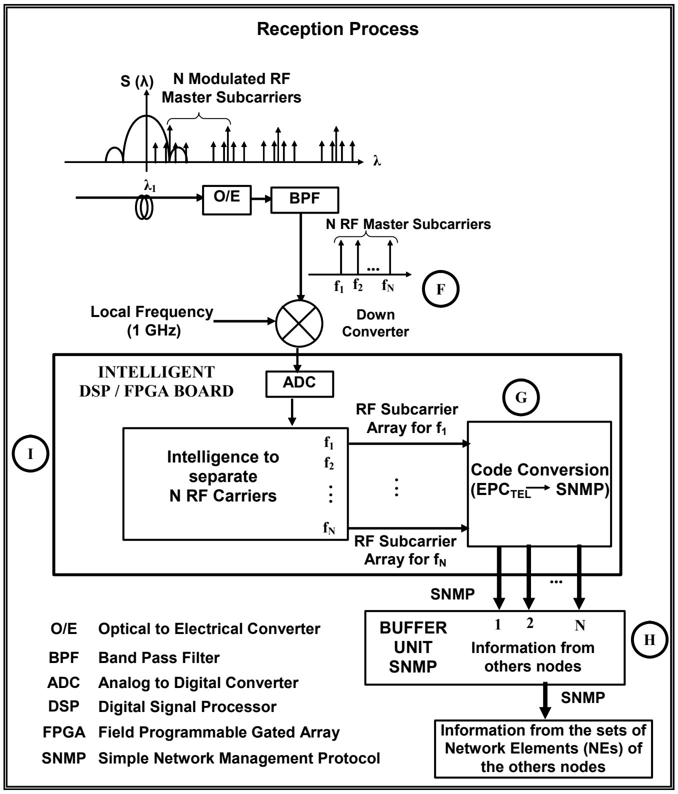

Figure 7. Block diagram of a generic optical network node using RF subcarrier array code inside optical domain – Reception Process

The EPCglobal, Inc., in order to establish worldwide standards, defined a global specification for designing and implementing RFID in supply-chain operations [6]. For doing so, in 1999 EPCglobal developed the Electronic Product Code (EPC), which is a worldwide code that uniquely identifies any item in a supply chain [15]. The EPC can be of different sizes: 32, 64, 96, 128, and up to 256 bit; currently the 96-bit EPC is the most used in EPC RFID tags in practice.

Using 96 bits it is possible to generate about 80,000 trillion of trillion different numbers. An example of a 96-bit EPC field structure is shown in Fig. 9 [6] [15].

In this work, is being used a code structure similar to EPC, formed by a 32-bit RF-subcarrier array which will represent the most important attributes of a NE and the main Telecom network characteristics – EPC Telecom.

Considering a 32-bit RF-subcarrier array it will be possible to define more then 4 billions different codes (2^{32} -1 = 4,294,976,295), such number should be sufficiently large to identify in a unique form the NEs, theirs attributes, and each node inventory in a telecom ring network. An array with more than 32-bits RF subcarriers could be used according to the needed information model.

The following characteristics and attributes will be considered in the implementation of this new code for each NE of the local node – as demonstrated in Fig. 2:

- NE type (WDM, SDH Multiplexer, ATM Switch, IP Router, Ethernet Switch, and others).
- NE friendly name.
- NE Total Capacity and Configuration.
- NE Granularity.
- NE Used and Available Capacity.
- Used capacity by a customer.
- Used capacity by a service.
- Node overall inventory.

An example of 32-bit RF-subcarrier array – EPC Telecom; field structure is presented in Fig. 10, where:

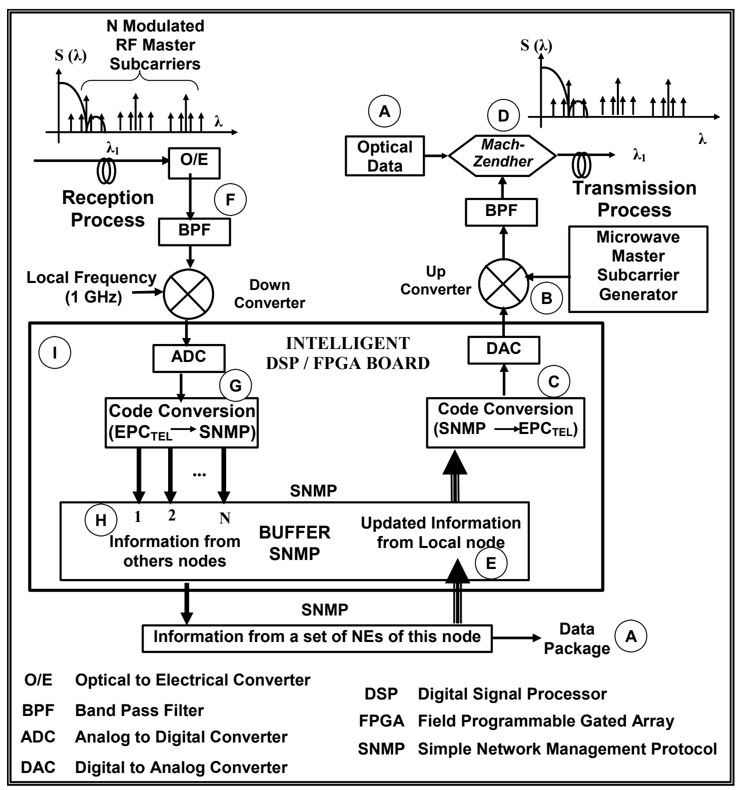

Figure 8. Block diagram of a generic optical network node using RF subcarrier array code inside optical domain – Total Process

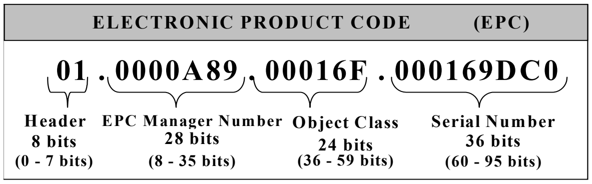

Figure 9. 96-bit EPC field structure

- Header identifies the presence of a transmitted code.
- NE Type may identify the NE type and friendly name.
- NE Capacity & Configuration indicates the NE total capacity, granularity and configuration.
- NE Used & Available Capacity indicates the NE currently capacity.

4.1. An application example

Fig. 11 presents an implementation example of this scheme able to introduce RF subcarriers in a WDM metropolitan optical ring for Gigabit Ethernet applications, comprising 16 nodes in approximately 100-km length. The RF subcarrier array will be added to only one traffic package and will circulate through the ring network as a "sniffing" package.

Considering the typical propagation velocity of light in an optical fiber of 200,000 km/s [16], applied to this metropolitan 100km-length ring, the necessary time to complete a single loop would be 0.5 ms. Even considering the processing time in each node around µs, this time may be negligible comparing to sweeping time of 0.5 ms. Hence, this unique network sniffing package will search information of each node every 0.5 ms, making real-time-updated the inventory system database of the network.

By implementing this, it is possible to obtain a distributed management, and after on the first loop, all nodes will automatically update their own databases with new information, coming from other nodes, as the process continues.

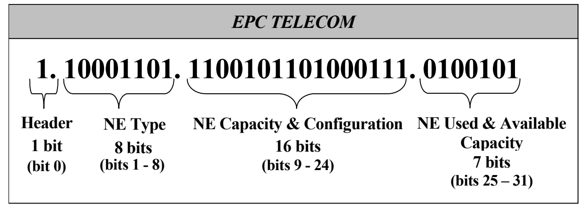

Figure 10. 32-bit RF-subcarrier array – EPC Telecom field structure

Using this circular sweeping property, it is possible to obtain a Map Manager of the optical ring, where a NE view may be displayed according its configuration. This capability provides immediate, distributed, and reliable information about the available capacity of the ring and its network resources, which allows for a detail analysis of ring usage and an effective design of ring extension.

5. Final comments, conclusion and future works

Since mid 90's, with the Telecom deregulation together with the necessity of convergence, a new Telecom competition scenario appears, involving among others, the traditional telephone carriers - voice focused; and Internet Service Providers (ISPs) - IP data focused [2] [3].

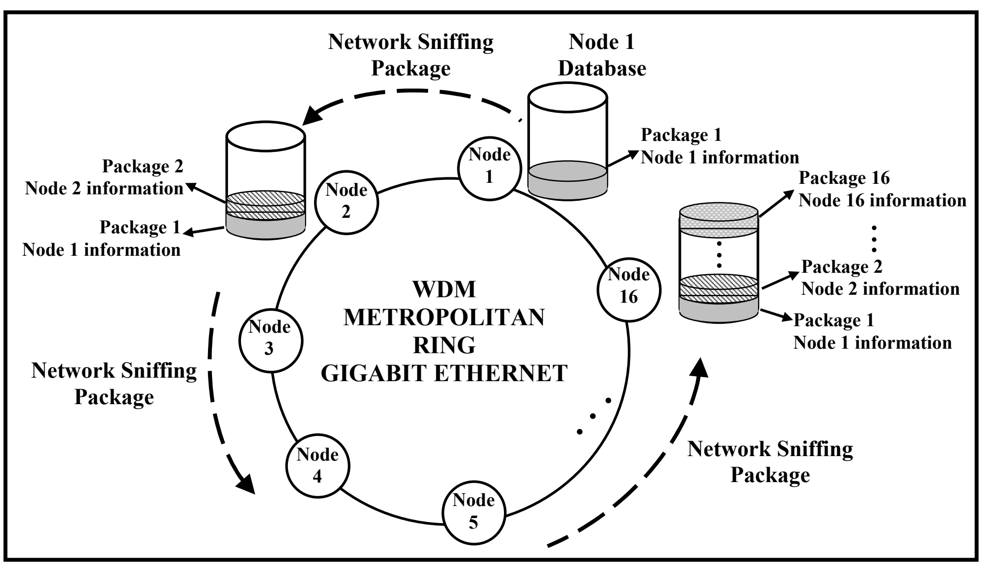

Figure 11. Block diagram of an example of the proposed system

Facing that, it appears the necessity to implement intelligence into the networks in order to obtain updated and accuracy data. A characteristic of the intelligent network in the new model is to offer and deliver service to customer - agility, flexibility, and increased network control from customer as indicated in a ring network. So it is possible to associate the necessity of having an end-to-end control of the network and real-time updated data – presented by intelligent networks – with the accuracy control management in a supply chain supported by RFID systems.

This work proposes then to implement – inside the optical rings of the telecom networks – the RFID technology, in order to use its associated logistics system design.

Using this technology and their intelligence in telecom networks, through the RF subcarriers introduction into optical domain, a new model of inventory management and service control will be generated.

Considering that in a typical RFID system with a 96-bit EPC code it is possible to have a control of supply chain products inventory of the world. With a code formed by 32-RF subcarriers array, it will become possible to:

- cover all telecom network NE attributes in a ring;
- obtain transparency – once this system could be applied to any technology;
- have interoperability – it is possible to use this system in parallel with other legacy operating systems (SONET/SDH, POS, ATM, Gigabit Ethernet, and others);

It should be highlighted that the main contributions of this paper are:

- dramatic time-reduction of network inventory update;
- development of a low level system able to interact with all management software tools including NGN and legacy applications;
- cost reduction in the OPEX (Operational Expenditure) costs of the network.

This new arrangement allows the introduction of intelligence on physical layer and improves the management process of Telecommunications Systems.

Besides the applications presented, one can foresee that by using a 32-bit code with over than 4 billions of different strings, a new taxonomy able to easily represent all network elements could be generated. The extensive taxonomy could demonstrate a significant capability in autonomic applications [17].

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