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NETWORK DATA PACKAGE OPTIMISATION FOR INLAND WATER MONITORING INFRASTRUCTURE

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Actually, the biggest problem of the inland water infrastructure is the access to a local broadband connection, in order to ensure enough data carrier availability from each local site both to the central Command Center but also to each local routing point (e.g. small harbors). Most of the modern infrastructure consists in automatic operating stations, specialized in environment and/or water quality monitoring, radar stations, radio local transmitters and other.

Keywords: Inland water monitoring system, GSM, radio, fiber optic, propagation, water sensors, AIS, radar, VHF.

1. Introduction

Any modern transport infrastructure involve additional facilities which are necessary in order to ensure travelers and goods safety, higher transport speed, reduced consumes, lower general pollution and not at last, better information systems. Particularly, inland water transportation needs informational systems in order to ensure skippers voice communication, central and regional command and control solutions, surveillance systems (radar, video and even infra-red spectrum surveillance), on-board data access (e.g. Internet, generally using GSM/3G/4G network), software applications, notices to skippers (text and optionally pictures), weather and environment monitoring.

Considering that all data has to be transferred from field to the central location (command and control station) in real-time, it is important to optimize the traffic and also to balance it between networks, if available. Actually, for inland water there is used in tandem many radio networks: regular analog VHF (according to IALA rules for the voice mobile naval radio), AIS digital radio (civil and military networks in parallel) and GSM/3G public operator's networks, which generally register well enough radio coverage over inland water. Locally, some IEEE 802.11x (WiFi) and/or WiMAX solutions are implemented as pilot solutions. Actually, the state of the art solutions integrates all three technologies, ensuring for the end-users all information as needed, no matter what kind of terminal they use.

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The radio networks are ground base infrastructure networks, optimized for data carrying service. Generally, for the VHF voice, AIS data and IEEE 802.11x / WiMAX broadcast networks the national or regional waterways administrators implement their own networks (both for broadcast, but also for carrier). On the other hand, the GSM/3G operators has their own infrastructure networks.

Thus, all transmission available technologies have to be considered, in order to optimize the infrastructure costs (especially CapEx (*Capital Expenses*) – initial costs) and also automatic balancing equipment will be installed at each location.

2. Motivation and analysis

The main necessity of modern inland water ways is logistic infrastructure coverage capable to ensure real time information both for skippers, but also for local authorities. Also, for coordination teams, the whole synoptically way image (communications, traffic, faults, events and other) is online deployed, being available on request on any terminal (PC compatible) connected to the system's data network. On the other hand, the modern infrastructure is implemented by automatic local stations, placed in fixed positions in order to ensure maximum efficiency for its purpose.

Up today, the experience shows that the optimum solution for an extensive data network is a hybrid solution using 2 or 3 physical networks: generally implemented using a fiber-optic networks and/or radio-link solution propriety of the inland water administration and a secondary solution provided by a public telecommunication operator, which deliver it as a service independent of technologies. This strategy ensures the optimum balance between investment, reliability and operational costs of the system.

The radio interface is general standardized and stable; most of the terminals providers accede to some of those directions. On the other hand, the infrastructure networks suffer of missing resources, generally because of the continuously increase of the real-time data flow.

In order to solve this problem, all the operators try to identify solutions for ensuring the necessary data flow by any available methods for each local capability in part: from data package compressing up to network capacity upgrade.

The data flow D necessary in the time unit (t) consists in the sum of subsystems needs:

$$\boldsymbol{D}\,(\boldsymbol{t}) = \sum_{\boldsymbol{k}=\boldsymbol{0}}^{\boldsymbol{n}} \left(\boldsymbol{Df}_{\boldsymbol{k}}^{\boldsymbol{n}}(\boldsymbol{t})\right), \tag{1}$$

where: $\boldsymbol{D}$ *is the total data flow (physical channel capacity) and* $\boldsymbol{Df}^{\,\boldsymbol{n}}$ *is the capacity which is necessary for the "*$\boldsymbol{k}$*" transmission.*

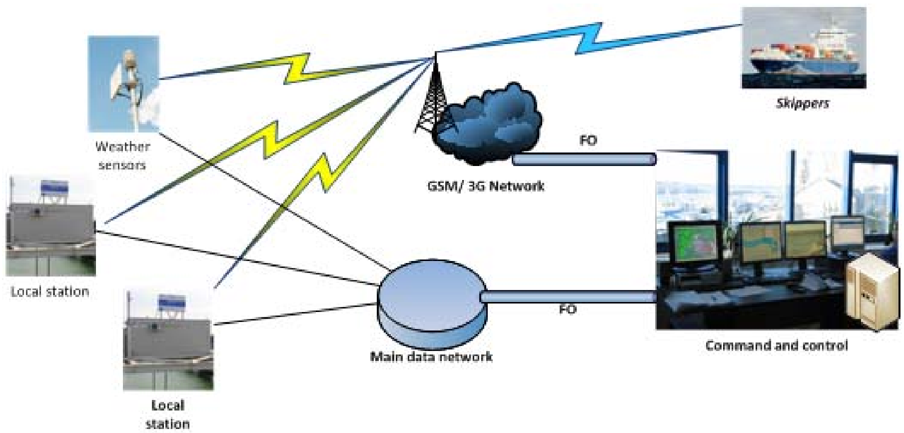

Fig. 1: Typical Data Infrastructure for Inland Water Monitoring Systems

Considering the transmission from each station to local communication tower (cell or relay), the communication can be shaped as Peer-to-Peer (P2P), and the model of necessary bandwidth needs the traffic characteristics for each of the two customers. The IP network has self-similar nature, according to Mark Crovella which exposed this propriety [6] and modeled it as an Ornstein–Uhlenbeck (OU) [5] process (known as reverting process):

$$\mathbf{dS_\tau = \gamma(\mu - S_t\ )dt + \sigma dW_t} \tag{2}$$

and starts on

$$\mathbf{S_\tau(0) = S_0} \tag{3}$$

the OU model can be simulated using the following form:

$$\mathbf{S(t) = S(0)e^{-\gamma t} + \mu(1 - e^{-\gamma t}) + \sigma\sqrt{\frac{1-e^{-\alpha\gamma c}}{2\gamma}}N}, \tag{4}$$

*where **S(t)** is the network available bandwidth and **N** is the number of simultaneously transmitting channels.*

In literature [3] the P2P model traffic supposes a heavy charge, thus the bandwidth is defined as an integration of OU process [4]:

$$\mathbf{B_W = \sum_{k=0}^{\infty} B(t_s)\Delta_S} \text{ and } \mathbf{\tau - t' = t_s} \tag{5}$$

$$\text{thus: } \mathbf{B_W = \sum_{k=0}^{\infty} B(\tau - t')\Delta_S}\ , \tag{6}$$

the sum of flows and can be considered by integral:

$$\mathbf{B_W = \int_{-\infty}^{t} B(\tau - t')\Delta_S} \tag{7}$$

and for instant bandwidth:

$$\mathbf{dS(s) = \lim_{t \to s} S(r, S)}, \tag{8}$$

*where “s” is defined in infinitesimal range and **Bw** is the total bandwidth,*

so:

$$\mathbf{B_W = \int_{-\infty}^{t} B(\tau - t')dS(s)\quad = \int_{-\infty}^{t} B(\tau - t')(\gamma(\mu - S)dt + \sigma dW_t)} \tag{9}$$

according to definition of OU process which allow substituting ***dS(s)***.Thus we obtain:

$$\mathbf{B_W = \int_{-\infty}^{t} B(\tau' - t)\gamma\mu \cdot dt - \int_{-\infty}^{t} B(\tau' - t)\gamma S_t dt + \int_{-\infty}^{t} B(\tau' - t)\sigma} \tag{10}$$

Generally, for using a single channel, is necessary a serial transmission, so the messages are organized sequentially, buffered from each subsystem. The main problem is that the high bandwidth consumers (such as CCTV systems) risks to generate less necessary traffic in restricted conditions and then flood the bandwidth over other systems.

$$\mathbf{B_{MAX} = \sum_{1}^{n} B_{W(i)}(s)}$$

$$\mathbf{= \textstyle\sum_1^n [\int_{-\infty}^{t} B(\tau' - t)\gamma\mu \cdot dt - \int_{-\infty}^{t} B(\tau' - t)\gamma S_t dt + \int_{-\infty}^{t} B(\tau' - t)\sigma]} \tag{11}$$

where $\boldsymbol{B_i(s)}$ *is the necessary bandwidth of each sub-system, and* $\boldsymbol{n}$ *the total number of sub-systems.*

Particularly, using a 3G / UMTS network, the operators introduce physically dynamic bandwidth limitations, in order to ensure traffic availability also for the other subscribers (end-users) according to their requests. Thus, it is necessary to introduce a dynamic buffer at each transmitter, in order to delay packets according to network availability [7]:

$$\mathbf{BP(b, t) = \frac{\log e^{bX[0,t]}}{bt}}, \tag{12}$$

where $\boldsymbol{b}$ *is the buffer size* $(\boldsymbol{b} > o)$*,* $\boldsymbol{t}$ *time or scale* $(\boldsymbol{t} < \infty)$ *and* $\boldsymbol{BP}$ *is the capacity (bps) in bits per second.*

For dimensioning the buffer, it is necessary to apply a Fractal Envelope Process estimator model [8] (FEP), which was developed with good results, for use in high speed networks. The FEP process estimation equation is:

$$\mathbf{EN = a + K^{\frac{H-1}{H}} \cdot (\sqrt{-2 * \ln(P_{loss})} * \sigma)^{\frac{1}{H}} \cdot H(1 - H)^{\frac{1-H}{H}}} \tag{13}$$

where: $\boldsymbol{BP}$ *is the buffer,* $\boldsymbol{a}$ *is the average,* $\boldsymbol{H}$ *is the Hurst parameter,* $\boldsymbol{\sigma}$ *is the standart devitation and* $\boldsymbol{P_{loss}}$ *represents the probability of packet loss when a buffer overflow.*

Considering $\mathbf{P_{loss} \approx 1\%}$ as acceptable, the "Modello FEP" generates the dynamic buffer necessary calculation for one hour, for P2P and HTTP in dynamic bandwidth conditions:

$$\mathbf{f_{op}} = \begin{cases} \frac{2}{5} \cdot \frac{EN}{\sqrt{b \cdot L}} \ \textbf{for } \mathbf{0.5} < BP < 0{,}7 \\ \frac{2}{75} \cdot \frac{EN}{\sqrt{b \cdot L}} \ \textbf{for } \mathbf{0.7} < BP < 1{,}0 \end{cases} \tag{14}$$

The decision for the technical limitation of the maximal bandwidth for each P2P is imposed by the operator, according to its network availability. The dynamic allocated bandwidth for each subsystem is a percent of the total available bandwidth.

Technically, the solution can be implemented using dedicated equipment (routers) which is capable to balance the traffic between the two (2) up-load ports, in order to transfer the traffic. But, the correct traffic balance is implemented according to dynamic limitations of bandwidth on each physical channel, determined in real-time by counting the total package upload capacity. Using a software signalization common instrument, each application will transmit to the router the requested traffic priority. This solution can be completely integrated, and the only difficulty could be the integration between different equipment vendors and the common routing equipment.

3. Case study

The case study applies to the Integrated Water Monitoring System of the Danube – Black Sea Channel, using 12 autonomous monitoring stations distributed along the channel (96 km total length). The communication system is implemented using VHF voice communications (analog), AIS digital data (the whole area is covered by 8 radio towers), local WiFi networks and an integrated RIS solution (named "Channel RoRIS" System). All data are integrated over a dedicated backbone, implemented over a fiber-optic network, owned by the Channel administrator and routed over both waterway banks. All over, every point of presence (the 12 autonomous monitoring stations and the radio towers) has as backup a 3G connection, ensured by a commercial operator (Vodafone) which ensures a 1,096 Mb minimal guaranteed bandwidth on each point – the requested network is a VPN (Virtual Private Network) over the operator infrastructure.

Practically, the system is based on a telecom infrastructure implemented on a fixed high capacity network integrated to the system and used by the owner for its only needs. Thus, the availability of the network is estimated to 99% on full capacity.

The back-up solution is the access to GSM / UMTS network available in the area. The connection is ensured using directional antennas to the closest direct-view GSM Cell – this implementation strategy ensures the best link capacity and connection reliability, but, on the other hand, it forces the operator to reserve the channel on cell for the end-user, eventually the hand-over to other cells being impossible.

The field analysis has been demonstrated the monitoring principles in real conditions and it has offered the data set both for project design fine tunings, but also for real result dissemination.

4. Results and Conclusions

The communication network for automatic monitoring stations for inland water management system can be modeled as a P2P network for each point to the local hub, preferable owned by the waterway administrator and implemented over regular, tested technologies. The usage of commercial GSM / 3G / UMTS is possible, conditioned by the hub load which can be dictated by instant resource usage. In order to solve this, the only solution is to ensure dedicated bandwidth for each station in part and to introduce a data buffer at each transmitter point (station), but also an automatic process delay or even reduced, in order to ensure the transmission for critical processes.

A particularity of the inland water ways is that those are generally covered by GSM and/or UMTS radio networks which can be used as voice and data carrier both for infrastructure systems and for the operators and skippers. This is a facility which is available only for inland water paths, for any other sea / ocean transport ways being impossible to access because of the small range communication technology. For these situations, the solution is the satellite link, even against the actually prohibitive OpEx price (*Operational Expenses*).

The optimum solution for an integrated management system is the hybrid implementation, using as main network a fixed facility (owned by the administration or rented as “black fiber network”) and a back-up solution offered by a local data-carrier operator, capable to ensure enough resources of fixed access for local / regional stations but also enough bandwidth for skippers communications. For medium and long term, this integrated solution will be able to replace the existing VHF communication with a new modern universal solution for integrated voice and data.

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