

Interoperability In Service For Over 30 Years: A Retrospective Analysis Of The Teletext Standard

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Abstract

Teletext was developed in the UK in the early 1970's to broadcast textual information to TV viewers, for display on demand. As a low-cost technology, with the information carried inside a TV signal, it has seen near universal adoption in Europe and Asia.

In this paper we examine Teletext as one of the first, and longest lasting, interoperability standards. We review the impact of a major technology evolution halfway through the life of this standard: the introduction of local storage memories in the TV sets. This evolution changed the Teletext information access paradigm from 'view when transmitted', to 'view cached information'. We note a number of user experience inconsistencies triggered by this paradigm shift, and place these in the context of standards creation and standards evolution.

Introduction

The radio and television broadcast industry is the longest running example of an open, interoperable service industry. Millions of television sets of various set makers can receive TV signals from numerous

broadcasters serving almost all countries throughout the world. The Teletext standard was an interesting development since its definition meant a change in dimension in connecting systems. Whereas the analog TV broadcast format standard definition (be it PAL, SECAM, or NTSC) is purely a matter of image lines on a display, the Teletext standard (ETSI, 2003) defines a structure in which information is partitioned in (content) magazines, pages and sub-pages, i.e. *a logical data model*. Whereas an analog TV signal is transmitted in a fixed order, broadcasters have considerable freedom in Teletext to choose which pages to transmit, in which order, and with which repetition rate.

In terms of Page's distinction of major dimensions in connecting independent systems (Page, 2004) this meant moving up a dimension. Page distinguished three main 'dimensions' in connecting independent systems, as follows:

- **Integratability:** aligning physical / technical connections between systems, including necessary hardware and firmware, protocols, etc.
- **Interoperability:** aligning exchange of data elements based on a common data interpretation, including the necessary software and implementation details for this exchange.
- **Composability:** aligning the underlying conceptual models of the connected systems including the purposeful abstractions of

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reality used for the conceptualization as implemented by these systems.

The defining characteristic of the last dimension, composability, is the ability to combine and recombine components into *different* systems for *different* purposes.

Whereas the analog TV signal definition belonged to the integratability dimension, Teletext was the first step in the next dimension. A data model, albeit simple, underlies the Teletext standard, and TV set makers and broadcasters must adhere to the data interpretation as defined in the standard. This is the realm of interoperability.

Interoperability

For interoperability, not only must data elements be transported from one system to the next, also the content needs to be understood in the same way by the sender and receiver. The content of these data elements (display, mark-up, and control information) is extracted from a semantic model inside the sending system. A receiving system must be able to relate this content, i.e. map it onto its own internal model.

We use the following definition of interoperability (Carney, 2005):

“The ability of a collection of communicating entities to (a) share specified information and, (b) operate on that information according to a shared operational semantics in order to achieve a specified purpose in a given context.”

This definition underlines that interoperability is a *relationship* between component systems (entities), which typically implies a form of *communication*. The definition however leaves open the nature of the relationship (technical and/or organizational) and how this relationship is created and managed.

The key challenges in achieving mass-scale interoperability are threefold:

- **Faithful definition:** To create (in a group of experts) a sound, correct, and inclusive

conceptual model for the information and interpretation of data elements being shared.

- **Ease of comprehension:** To make this conceptual model easily accessible, understandable, implementable, and usable by non-experts.
- **Evolution readiness:** To make this conceptual model open to changes in the future where new needs and options may merit (backwards-compatible) changes to both the conceptual model and its realization.

Whereas the first challenge is commonly recognized, the second and third one are normally not widely acknowledged.

The success of achieving interoperability in industrial practise however demands attention to all three issues. In comparison with company-internal systems development, added complexities in the design and deployment of interoperable systems are: i) the lack of an overall authority for a complete project; ii) the lack of synchronization of system(s) development and introduction.

Quality criteria for interoperability.

Success of an interoperability standard depends on both the value proposition as the underlying quality of the service chain. This underlying quality can be assessed by a number of quality aspects:

- Empirical quality
- Syntactic and semantic quality
- Pragmatic quality
- Social quality

Ultimately, the quality of a deployed standard can be quantified in practise by measuring error frequencies. This so-called *empirical quality* (Krogstie, 2003) can be attributed to either the quality of the standard's definition, the standard's ease of comprehension, or the standard's evolution readiness.

To achieve a faithful definition, the conceptual model must have good *syntactic and semantic quality* (Lindland, 1994). That is, the model must be expressed correctly in

the syntax and vocabulary of the chosen language (syntactic quality). Furthermore, the model must be a valid representation of the domain, and cover all needed domain aspects (semantic quality).

To achieve ease of comprehension, the conceptual model and the specification must have good *pragmatic quality* (Lindland, 1994). Pragmatic quality can be achieved by modelling with simple, clear and orthogonal concepts, well documented by guidelines. Models which are automatically interpreted (e.g. as Teletext decoders inside TVs do) need well-specified operational semantics to achieve unambiguous interpretation. Ease of comprehension is also a prerequisite to achieve *social quality* (Krogstie, 2003), i.e. agreement of all participants on the interpretation of the model and the interoperability standard.

To achieve evolution readiness, the conceptual model and the specification must be adaptable to future needs. Some future needs can be anticipated; others remain to be discovered throughout the operational use of a standard. Both *syntactic quality and semantic quality* are important for evolution readiness: to provide a sufficiently rich modelling language and room for extension – in concept and model structure.

Future needs for a standard may be born due to the following (Krogstie, 2006):

- **change in goals:** e.g. new information / content to be relayed
- **change in domain:** e.g. improved methods to relay information/ content
- **change in knowledge:** e.g. of standardization experts
- **change in interpretation:** e.g. different ways to use/interpret relayed information by humans or tools

Ultimately, consequence of these changes could be to consider a change in modelling language (Krogstie, 2006). Interoperability standards in their design need to allot capacity and spare room to accommodate future results

of ongoing learning requiring model revisions and extensions.

Interoperability standards are, apart from a specification, also a tool for communication between independent parties. Thus, these three categories are appropriate to evaluate the quality of an interoperability standard.

Teletext

Teletext was developed in the UK in the early 1970's to broadcast any sort of information to its audience. It has seen tremendous adoption throughout Europe and Asia. In those parts of the world, a large majority of TV broadcasters provide a Teletext service: e.g., news, weather, sports, and TV guide information. Currently all but the utmost low-end televisions sold in Europe and Asia can display Teletext pages. Teletext has proven to be a reliable text news service during events such as the September 11, 2001 terrorist attacks, during which the web pages of major news sites became inaccessible due to unexpected demand (Wikipedia, 2009).

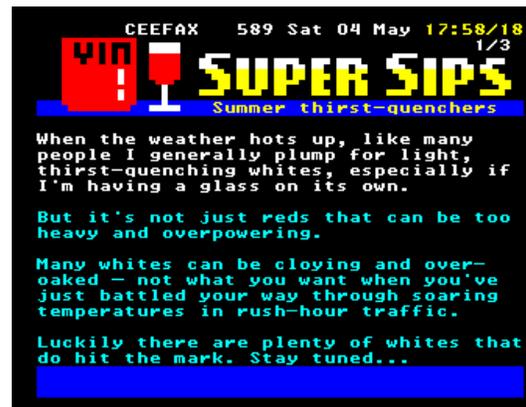


Figure 1: A standard Teletext page

The original Teletext standard (a.k.a. level 1) supported Teletext pages consisting of 24 rows of 40 characters, chosen from a limited set of characters, in a fixed colour palette. Figure 1 shows such an information screen. Since then, Teletext has evolved considerably. Later version standards, amongst others, extended the character repertoire (level 1.5),

increased the color palette, provided side panels for additional text and graphics (level 2.5), and introduced different font styles and proportional spacing (level 3.5) (ETSI, 2003).

The Teletext conceptual information model. Teletext partitions information into eight magazines (e.g. for news, TV guide, etc.). A magazine contains a number of pages. For example, a sports news magazine typically contains pages for basketball, baseball, and hockey. A Teletext page is identified by a three digit number. The most significant digit specifies the magazine number. A page number is typically fixed to a subtopic within a magazine. For example, page 201 typically gives the TV schedule of today.

Pages and sub-pages. When the information of a subtopic doesn't fit on a single screen, it is distributed over a number of sub-pages. A page with sub-pages is also called a rotating page. Pages may change from single pages, to pages with sub-pages depending on information needs. For example, a soccer match report starts before the kick-off listing only the line-up of both teams. After 45 minutes, the report includes a description of the first half. After the final whistle, the report then includes a description of the second half.

Teletext performance. Pages in a magazine are broadcasted serially. The order of the pages is not specified in the standard, but left to the broadcaster. The broadcaster, being aware of the content, can thus optimise performance (Ammar, 1987). Of course, the Teletext standard provides a number of features to support a broadcaster in achieving the desired performance (ETSI, 2003). One aspect of the performance is the access time of the different Teletext pages. To control the access time, both objective and subjective, Teletext provides, amongst others, the following concepts:

- **Rolling headers** inform the users about the pages being received, and positively influence the subjective access time. Rolling headers require a sequence in the numbers of the broadcasted pages.

- **Out of sequence broadcasts** enable that popular pages, e.g. the start page, can be broadcasted more frequently than the others without interfering with rolling headers. Out of sequence broadcasts reduce access time for popular pages.

Other performance aspects include the time available to read information and robustness for bad reception. These aspects are addressed in Teletext by allowing repetition of sub-pages of a rotating page. Three sub-pages can be broadcast as either 1,2,3, or 1,1,2,2,3,3, or 1,1,1,2,2,2,3,3,3, etc.

Impact of a major technology evolution in Teletext decoders. Since the introduction of Teletext in the early 1970's, the price of DRAM memory did considerably drop. This enabled a new kind of Teletext decoders, as already envisioned early on (Chew, 1977) (Tanton, 1979). They provide the Teletext viewer a requested page directly from memory instead of having to wait for the page to be transmitted. The negative side effect of this feature is the possibility that obsolete information is provided to the Teletext viewer. Therefore, such decoders must maintain consistency between the broadcasted and stored information.

Technology evolution and standards In the context of a standards process, typically one observes that the possibilities of such a technology change are exploited as a competitive product advantage first. Companies do not wait for an evolution of the standard. Net consequence often is that such a change is never standardized anymore. Also, technology evolution many times results in an incremental, yet incompatible standards succession: DAB+ is not backwards compatible with DAB, neither is IPv6 with IPv4, nor XML with SGML (Egyedi, 2002).

Experimental study of decoders

This section reports on a study we undertook to chart the variety of realizations

of Teletext page storage handling policies in TV sets. The objective of this study was to examine how a (disruptive) technology change may impact the quality of interoperability.

In this study we evaluated differences in information obsolescence handling policies, and probed broadcaster practises (including potential standards interpretation issues).

Introduction. For this experimental study, we used a number of televisions from various brands. We looked at the Teletext pages available to a TV viewer after having been tuned to the same channel for several hours.

This amount of time is sufficiently large for the broadcasted information to have undergone changes. Such a scenario is realistic in a user context: watching Teletext after a movie would give similar experiences.

We compared the Teletext pages available to a TV viewer with the pages present in the actual broadcast. To determine the currently broadcasted pages, we either used a TV without memory to store Teletext pages, or we erased the stored Teletext pages from the television's memory either by zapping to another channel and back; or by turning the TV off and on again (power cycling).

We took pictures of the screen of those TVs whenever we observed a difference in available and broadcasted Teletext pages. Note that we highlighted areas of interest in those pictures using a simple drawing tool.

Observation: Pages with and without sub-pages. According to the Teletext standard (ETSI, 2003), a Teletext page can be associated either with no sub-pages (coded 00) or with sub-pages (coded 01 till 79). The syntactic difference (Lindland, 1994) between pages with and without sub-pages is thus small: it only depends on the actual value of the sub-code.

We hypothesize that this small syntactic difference is the cause of a number of violations of the Teletext standard as exemplified in Figure 2 and Figure 3.

The Teletext standard would have benefited from a more explicit distinction between pages with and without sub-pages (improvement in the pragmatic quality).



Figure 2: Broadcaster usage of 01 for a single page without sub-pages (yielding a useless navigation bar).



Figure 3: Broadcaster usage of 00 for page with sub-pages.

Observation: Rotating Advertisements. Commercial Teletext broadcasters typically reserve part of a page for advertisements. This part, they want to change independently from, and more often than, the content the user is interested in. To handle this situation correctly on all decoders, the Teletext standard (ETSI, 2003) introduces in a note besides the concept of a page with no sub-pages (coded 00) and with sub-pages (coded 01 till 79) the concept of a page with one sub-page (i.e., a rotating advertisement). We think that the standard is not clear enough about this concept. Consequently, some broadcasters wrongly

implemented a page with rotating advertisements as a page with sub-pages, i.e., a rotating page.

On a sub-page collecting decoder, we observe three unwanted results.

1. Storage is wasted by storing the same page multiple times,
2. The user perceives an inconsistent UI: a single page (denoted by 1/1) has a sub-page navigation bar suggesting multiple sub-pages,
3. The likelihood for a commercial advertisement to be viewed is not uniformly distributed: Teletext viewers will not move to the sub-pages with the higher sub-codes to read the advertisements. They observe quickly that “real” content does not change.

Observation: Dynamics of content.

According to the Teletext standard, a Teletext page can be in the following states:

- Page not in transmission
- Page without associated sub-pages (coded 00)
- Page with sub-pages (coded 01 till 79)

In Figure 4 we have captured the dynamics of a Teletext page using these three states. Neither a picture, nor an explanation of the page dynamics is contained in any of the Teletext standard documents. In terms of pragmatic quality (i.e. ease of comprehension) the standard is poor on this aspect.

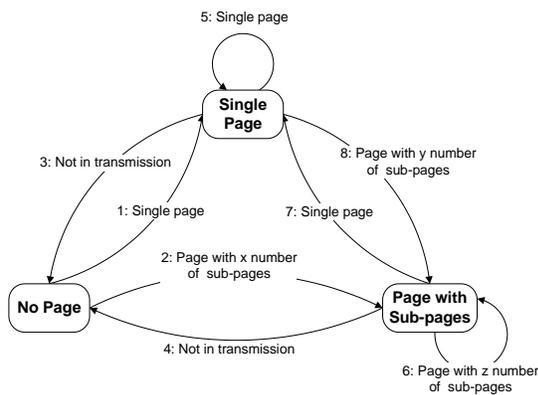


Figure 4: Transitions and states in the life of a page in Teletext

We previously described a soccer match report that grows over time. How should this report be handled by the Teletext broadcaster?

Initially, the soccer match report fits on a single page, and thus is coded 00. When the report grows beyond a single page it changes into a page with sub-pages: encoded 01 and 02. The content of sub-page 01 and the original single page 00 will typically be the same; the new information is only appended. Despite the fact that the original standard (BBC, 1976) contains a control bit to signal that a page should be not be confused with an earlier broadcasted page, we observed on a number of brands that changes in the content of a Teletext page results into inconsistencies between the currently broadcasted and stored information.



Figure 5: TV which combined a page with and without sub-pages broadcast after each other.

Figure 5 shows the results of an incorrectly handled transition from single page to a page with sub-pages (or vice versa).

The original standard (BBC, 1976) did not introduce the concepts of states, but only the concept of a transition: the erase page control bit signals that the currently transmitted page “is significantly different from that in the previous transmission [...], such that the two should not be confused”. Transmission of an instantaneous event over a noisy communication channel without reception acknowledgements is error-prone. For robustness and consistency, it would have been better if the current state was encoded into the Teletext page. Whenever a new state is observed the obsolete page is erased from memory. This too applies to the Update Indicator control bit, with which an editor can

signal (once only) a major content change for a page.

The usage of time-stamps would be an alternative to erase obsolete pages from memory. Obsolete pages are then eventually erased, albeit not instantly as by an erase flag associated with the arrival of a new page.

Observation: Absence of information is not transmitted. The original standard (BBC, 1976) allowed that lines that contain no information (e.g. empty lines) need not be transmitted. This same standard also allowed for incomplete page updates, only containing updated parts. Such features save some bandwidth. However, since communication occurs over a noisy channel, many TV brands only erase information when newer information is correctly received. Combined, this leads to the following observed errors.



Figure 6: Teletext page with empty lines containing obsolete information.

In Figure 6, lines appear that should have been empty: they contain information of an earlier broadcasted page.

Summary of observations. On all brands of televisions, we observed errors in Teletext functionality. A few were caused by broadcasters violating the Teletext standard due to interpretation errors (caused by a lack of comprehension). Most errors though were caused by changes in the broadcast content. This resulted in obsolete information being mixed with currently broadcasted information. We observed this phenomenon both at sub-page level and within a single page. We judge

these errors as the result of a lower semantic quality of Teletext standard: the specification of dynamic behaviour is (almost) completely absent in the Teletext standard.

Gauging the success of Teletext as an interoperability standard

Teletext is a prime example of a commercially successful interoperability standard. As a low-cost technology, it has seen tremendous adoption throughout Europe and Asia. In those countries, a range of Teletext services can be displayed by the vast majority of TV sets from various suppliers by virtue of a built-in Teletext decoder. The value proposition of Teletext was unique at its launch. After thirty years, even in today's emerging "always-on" culture, Teletext remains a reliable source for information.

In terms of empirical quality of Teletext in use has been good, but not perfect. Our observations show that real problems do occur in practise. The introduction of a technology evolution, page-collecting Teletext decoders, has even increased the error frequency.

In this section we summarize our observations into a quality assessment along the three categories and quality criteria as defined in the section "Interoperability".

Faithful definition. The category of faithful definition assesses whether the conceptual model for the information and interpretation of data elements being shared is sound, correct, and inclusive.

In terms of syntactical quality, the Teletext standard is not robust with respect to the notification of a change in content. According to the Teletext standard, a change in content should be communicated by a single change event (the erase page control bit). This method does not guarantee consistency between the broadcaster and receiver: the event can easily be lost in a noisy communication channel from broadcaster to receiver. For robustness and consistency, it would have been better

when the actual state was encoded into a Teletext page. A difference in state would then prevent confusing the content of two successively broadcasted pages.

In terms of semantic quality, the definition of Teletext falls short in the specification of dynamic behaviour. The standard has the following deficiencies:

- The element of change is not made explicit.
- Life-time of a single element is unclear.
- The life-time of the content of a single element is left unspecified.

The Teletext standard does not specify the element of change. Is it a page (including all its sub-pages), a sub-page (including all its meta-data), or a line?

With partial updates, not transmitting the absence of information, and rotating advertisements, it is not clear which groups of transmitted information belong together, and which update each other. Many of the observations reported here can be traced back to a lack of consideration and specification of the dynamic behaviour.

The Teletext standard does not specify the lifetime of an element, nor absolute or relative to other elements. The impact of this omission did become larger with subsequent extensions of the standard. For example, in level 1.5 meta-data is introduced that can overwrite a character on a level 1 line, yet it is not clear whether this meta-data remains valid when that particular line is updated.

Ease of comprehension. The category of ease of comprehension assesses whether the specification makes conceptual model easily accessible, understandable, implementable, and usable by non-experts.

In terms of pragmatic quality, the Teletext standard would have benefited from embedding the total number of sub-pages in its header. On page with sub-pages, common broadcast practice is to incorporate such information, e.g. using notations like 2/4. Many single pages even contain such

information. Such information (in machine-readable form) would have simplified the user interface of a decoder with local storage memories (the sub-page navigator bar), and reduced the complexity to keep a receiver's content consistent.

In terms of social quality, the understandability of the Teletext standard is poor with respect to the difference between pages with and without sub-pages. First, why is the distinction needed, since one could also define a page as having one or more sub-pages? Second, the distinction based on the value of the sub-code (either 00 or 01 till 79) is small and results in poor pragmatic quality as exemplified by the errors reported here.

The usability for non-experts of the Teletext standard is limited since (in our opinion) too little attention has been paid to the dynamic behaviour. Apart from lack of definition of the elements of change, also the various states of a page's content are not explicitly defined. The Teletext standard would have benefited from a state diagram as depicted in Figure 4. Rules and guidelines for these state changes could have avoided many of the here reported problems.

Evolution readiness. The category of evolution readiness assesses whether the conceptual model is future-proof and open to changes in the future where new needs and options may merit changes to both the conceptual model and its realization.

Two aspects are important in the context of interoperability standards: the syntactic and semantic quality to accommodate future needs.

Evolution-readiness has been key to the success of Teletext; this standard has evolved considerably since the early 1970's. The original standard (a.k.a. level 1) supported Teletext pages consisting of 24 rows of 40 characters, chosen from a limited set of characters, in a fixed colour palette. Later standards extended the character repertoire (level 1.5), increased the colour palette,

provided side panels for additional text and graphics (level 2.5), and introduced different font styles and proportional spacing (level 3.5). We consider the following syntactical and semantic properties of the standard (BBC, 1976) through (ETSI 2003) to have enabled this success:

- **Self-descriptive format.** For example, the line number within a page is not implicit defined by the order of broadcast, but is explicitly encoded in the broadcasted information (BBC, 1976). This feature enabled that multiple lines with the same number 26 could be associated with a single page.
- **Explicit ignorance of unknown values.** For example, lines numbers in the range 24-31 may be transmitted but must be ignored (BBC, 1976). This feature enabled the extension of the character repertoire to use line number 26.
- **Room for extension.** For example, three control characters were reserved for future use (BBC, 1976). These control characters were later used to control the national option character subset (ETSI, 2003).
- **Hierarchical structure in the transmitted data.** The hierarchical structure into service, magazine, and page levels was already present in the original standard (BBC, 1976). It became however more explicit in the later standards (ETSI, 2003).

In terms of creating extensions in the standard for new or improved functionality, Teletext was hugely successful. These extensions however also magnified its omissions, such as the lack of specification of dynamic behaviour, e.g. the lack of a well-defined ‘element of change’. Teletext was developed together with the British public service broadcaster, the BBC. Advertisements were initially not considered, yet for commercial broadcasters they are essential. Commercial broadcasters want to change the advertisements independently from, and more often than, the rest of the page. In our view, the element of change has never been properly stated, leading to some of the errors reported.

The Teletext standard enables that only those parts of a page that contain actual content, or that are updated, need to be broadcast. The downside of this approach was known from the start (Chew, 1977):

“It is moreover desirable, when working adaptively, that all pages should occasionally be transmitted in full to “sweep up” any accumulated errors which may be causing unwanted characters to be displayed on otherwise blank rows. Such erroneous characters would otherwise remain on display indefinitely”.

With storage, this downside is not limited to the page on display, but applies to all pages. Today, the perceived advantage of saving bandwidth does not outweigh this drawback anymore, especially, since most broadcasters seem not aware of this issue.

The designers of Teletext decoders hence must struggle with the lack of definition of dynamic behaviour. Local strategies are often built into decoders to handle dynamics of Teletext transmissions and to minimize any out-of-date or incorrect information.

Conclusions

In this paper, we have evaluated the strength and weaknesses of Teletext: one of the first mass-deployed interoperability standards. First, we have set out to specify necessary quality criteria: not only for the purely technical definition part, but also for ease of comprehension and evolution readiness. Subsequently, we have described the Teletext standard, and given empirical evidence of problems in terms of these quality criteria. These problems were worsened by a major technology evolution halfway through the life of the Teletext standard: introduction of local storage memories in TV sets.

Overall the Teletext standard has seen tremendous success. Its operational use spans already thirty years with almost universal adoption rate for TVs sold in Europe and Asia. The standard itself has undergone several upgrades to introduce new or improved

functionality while maintaining backward compatibility for old TVs already sold.

On technical level, the Teletext standard was an interesting development since its definition meant that for the first time broadcasters got considerable freedom in transmission strategy: they could choose what pages to transmit, in which order, and with which repetition rate. The standards definition was sufficiently flexible to support several evolutions. In retrospect however, the omission of specification of the element of change and dynamic behaviour did cause significant problems for Teletext decoders. More guidelines and explanations would have eased comprehension, and helped alignment of broadcasting practises with decoders.

The Teletext standards history contains two important lessons for all interoperability standards. Firstly, although standards creators (e.g. Chew, 1977) may have had a good vision on evolution and potential problems, it is still necessary to capture these issues explicitly in standards, either by rules or guidelines. Informal statements on e.g. the necessity to “sweep up” accumulated errors were never formally incorporated, and hence unknown to large parts of the community. Secondly, upgrading of standards already in operational use to handle technology evolutions (such as page-collecting decoders), is difficult, if not virtually impossible. Such technology evolutions are marketed as competitive differences, hence there is no interest to announce, and even less to wait first for a standards upgrade before launching such a unique selling point. Hence, standardisation activities should have a long-ranging vision, such that new options can be incorporated in a pre-competitive stage. RDS (IEC, 2009), instituted for that purpose an “Open Data Application” concept: new applications could be compatibly added and signalled with a new Application ID.

Notwithstanding the above issues, the Teletext standard is a fine example of a

working interoperability standard holding its place as information source well into the age of Internet.

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