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CONCEPTS IN ROUTING, PRIORITY AND MESSAGE STACKING IN RELATION TO LARGE DISTRIBUTED AUDIO SYSTEMS

P.H. Scarbrough (1) and P.W. Barnett (2)

(1) Jaffe Acoustics, Norwalk, Connecticut, U.S.A.

(2) AMS Acoustics, London, U.K.

INTRODUCTION

Large scale public address systems which accommodate multiple simultaneous users must employ logical schemes for allocating access to ensure that users are not frustrated in their attempts to communicate with listeners.

In the past it was common to employ the related concepts of muting, routing and priority to accomplish this goal. While effective when used in combination, these concepts alone will not guarantee free and unfettered access to the system. Accordingly it is essential to overlay an additional capability, message stacking, to fully realize this goal.

The authors intend to examine issues related to the design of systems employing these concepts and to discuss their application in the recently completed audio systems for the new Macau Jockey Club.

MUTING

In simple systems it is obvious that output muting may be employed to ensure that the input of a single microphone is directed only to the desired loudspeaker or output zones. In practice, the mute switches are normally set open and the operator selectively unmutes outputs to initiate a page to specific output zones. In small systems with relatively few output zones it is possible for an operator to become quite proficient at directing messages to the desired areas. Of course, as the size of the system grows, so too does the number of potential combinations. Indeed, the number of *combinations*, **C**, rises according to Equation 1:

$$C = \left(\sum_{n=1}^{N-1} \frac{N!}{(N-n)!} \cdot \frac{1}{n!} \right) + 1$$

where: **C** is the number of unique combinations of output zones
N is the number of output zones, an integer greater than 1
n is an integer

As the number of inputs is increased, the number of mute combinations remains the same, but the number of unique *paths*, **P**, is represented by Equation 2:

$$P = I \cdot \left[\left(\sum_{n=1}^{N-1} \frac{N!}{(N-n)!} \cdot \frac{1}{n!} \right) + 1 \right]$$

where: **I** is the number of inputs, an integer greater than 0

ROUTING, PRIORITY AND MESSAGE STACKING

One can design a system with many inputs and output zones and rely entirely on muting. While the number of paths may become quite large, the number of paths in use at any one moment in time which we will call the *instantaneous throughput* may never be greater than one.

DIFFERENTIATING ROUTING FROM MUTING

While it is possible to design a large system using only muting concepts, it is readily obvious that such a system lacks flexibility and imposes unreasonable limitations on the users.

As the number of users grows, it becomes desirable to allow system access to more than one user at a time. Simultaneous access by more than one input or instantaneous throughput higher than one can be accommodated by employing routing, that is the active direction of inputs to specific outputs.

Routing allows multiple simultaneous paths. In fact, the instantaneous throughput may be equal to the total number of inputs *provided* that the path desired by any user does not overlap that desired by any other user. While in theory this appears to be a significant improvement in system capability, in practice one soon finds that such systems are oftentimes little better than muting based counterparts.

PRIORITY

One obvious way to improve routed and muted systems is to employ priority systems. By using priority systems, one or more inputs may exercise privileged access to the system. Priority may be of two types, simple priority systems which employ input muting, that is a means through which lower priority inputs are automatically muted upon initiation of access from a higher priority input; and layered priority systems which employ selective over-ride functions such that a higher priority input over-rides lower priority inputs *only* in output zones affected by a higher priority access.

Simple priority readily allows lower priority users to know that their access privileges have been terminated, but does not improve instantaneous throughput, it merely organizes system access using a predetermined hierarchical model.

Layered priority enables one to develop systems which allow for instantaneous throughput that approaches the maximum (i.e. a number of simultaneous paths equal to the number of inputs). While layered priority does vastly improve instantaneous throughput, it also has a significant disadvantage in that lower priority users can never be assured that their message has been delivered to all of the intended output zones.

A practical system might typically employ both types, e.g. a system can be designed in which normal messages use layered priority while emergency messages use simple priority.

It must be noted that while priority driven systems will work, they all suffer a major disadvantage in that they allow messages to be interrupted while they are in progress. This is frustrating to the user who must then repeat his message (if indeed he even knows he has been interrupted) and to the listener who is never certain that the message he was intended to hear has, in fact, been re-issued.

THE MYTH OF INSTANTANEOUS THROUGHPUT

Until now, we have discussed means via which one can improve instantaneous throughput. We have seen how muting, routing and priority can be combined to effect a logical scheme for allocating access to multiple users of large distributed audio systems. But the result is far from perfect and in fact one must trade-off a certain measure of reliability (i.e. assurance that all messages reach their intended audiences) to create an acceptable level of throughput.

Having gone through this exercise we are forced to ask ourselves the following: Of what value is high instantaneous throughput if reliability is significantly reduced? If one concludes that both high reliability and simultaneous access by multiple inputs is essential then one must abandon the concept of high instantaneous throughput, for it is not possible under most circumstances to achieve both.

INSTANTANEOUS ACCESS — MESSAGE STACKING

Once one abandons the mythical goal of high instantaneous throughput, the solution to the problem becomes obvious. If one studies the operation of large distributed audio systems, one will discover that the actual amount of time that the system is in use is quite limited. If integrated over time one can see that the desired accesses often fall well within the throughput capability of even a simple non-prioritized muting system. Unfortunately at any particular moment in time this may not be the case. Accordingly, the real need in any large distributed audio system with many inputs is high instantaneous access.

High instantaneous access can be afforded by using message stacking, that is a means by which each input may be directed into a system which stores the incoming message. Stored messages are then released in the order that they are completed.

Message stacking has many advantages, among these are:

1. Many users may be granted simultaneous access to the system.
2. High reliability is assured—every message will be delivered to its intended zones.
3. Priority functions may be overlaid on the message stacking system.

CASE IN POINT — THE MACAU JOCKEY CLUB

In racecourses audio programs play an important role in the delivery of information to the punters (bettors) and heighten the excitement generated on the course. In addition to public address functions, the audio systems work to improve administrative functioning of race and betting operations. In both instances, the improvements yielded by a well designed audio system ultimately lead to enhanced revenue.

ROUTING, PRIORITY AND MESSAGE STACKING

The audio systems at the new Macau Jockey Club illustrate how the concepts described above were integrated to develop a system which is highly flexible and accommodating to the users. The design of these systems is based upon a detailed analysis of the the function of these unique public assembly buildings and the authors' considerable experience with two previous installations for the Royal Hong Kong Jockey Club courses at Happy Valley and ShaTin.

RACECOURSE OPERATIONS — AN OVERVIEW

Racecourses employ highly structured and methodical procedures to ensure the smooth and efficient operation of the betting system. With millions of dollars at stake in every race, the swift dissemination of information becomes crucial to preventing losses for either the punters or the course. While tote boards and other visual systems play an important role in this process, audio systems, by virtue of their comprehensive coverage of the course, represent the most efficient and reliable means of delivering critical information to the punters. This coverage also makes the audio system an effective means of locating particular persons throughout the course.

In addition to supplying critical race related information and pages, the audio systems can function to entertain the punters, heighten the excitement of race meetings and, working in concert with a closed circuit television (CCTV) system, add to the colour and pageant of the proceedings.

Finally, the audio systems serve a crucial life safety function. In the event of an emergency, the audio systems represent the swiftest and most reliable means of directing instructions to both staff and the public. One need only look at the regrettable loss of life at Hillsborough and the King's Cross Underground station fire to appreciate the utility of well designed audio systems as a means of panic control in large public venues.

Of course all audio systems should be designed with due regard for the benefit which will accrue from their use. Whilst the approach to design articulated here may seem excessively complex — and therefore costly — systems such as these can be justified financially. Promotional time can be marketed and sold much as advertising access is sold on large screen television screens in many large stadia today. In addition, promotional messages may be easily targeted to specific audiences who are known to frequent particular areas of the course. Some advertisers would be willing to pay quite handsomely for access to select groups such as the individuals who inhabit the posh members boxes on the fourth floor of the grandstand. On this basis it becomes possible to justify the capital investment required in such installations as a direct return on that investment can be gauged.

DESIGN OF AUDIO SYSTEMS AT THE MACAU JOCKEY CLUB

The Macau Jockey Club is situated on Taipa, one of two islands in the Portuguese enclave of Macau, some sixty-five miles west of Hong Kong. The course, built by Taiwanese business interests, attracts punters from both Macau and Hong Kong.

ROUTING, PRIORITY AND MESSAGE STACKING

The international nature of this project required designs which afforded facilities for four languages, Cantonese (the language of the resident Chinese population of Macau), Portuguese (Macau is still under Portuguese administration, at least until 1999), Mandarin (the language of the Taiwanese backers of the project) and English (the one language common to Macau, Taiwan and Hong Kong and important given the large expatriate British community in Hong Kong).

To develop the design for these systems we analysed the different inputs to the system and classified their access according to importance (priority), access requirements (i.e. the areas of the course to which the input has access) and length of message. This analysis enabled us to organize the system into blocks containing inputs of a similar type and function. The input definitions are as follows:

INPUT	DEFINITION
Police	This single paging station with a simple hand held microphone is the designated emergency paging station for the local police forces. A page originating from this station is automatically assigned emergency priority and is directed to all areas of the course.
Security	Three stations, one in each of the three major course buildings, i.e the Grandstand, Race Center and Computer Complex. Stations can initiate emergency messages, local security staff calls (i.e. security staff areas within the building), all security staff or a local all page function.
Main Announcers	Four paging stations are provided, one for each language. These can access various areas of the course by function, i.e. race information, promotional message, pages of public/members and race staff areas.
Administration	One paging station is provided for the use of the central telephone system operator. On non-race days, one can call the operator and ask for a page to be sent out to particular course buildings or to the entire course.
Technical Office	A single station located in the PA Control Room allows technical staff to test and set-up the systems. This station may access any area of the course.
Betting Control	This single station is provided to allow the Betting Control Officer to communicate primarily with the Betting Operations Officer and secondarily to On-Course Betting Booths and Off-Course Betting Centres (OCB).
Betting Operations	This single station is provided to allow the Betting Operations Officer to communicate with betting supervisors and staff in On-Course Betting Booths and Off-Course Betting Centres (OCB).
CCTV	Four inputs, one for each language, are provided to receive audio feeds from the CCTV studios on the course. This includes the audio associated with pre-race CCTV programmes as well as special entertainment and promotional videos. Race commentary also originates in the CCTV studios.
Cassette Decks	Background programme source, two inputs provided.
CD Player	Background programme source, one input provided.
Tuner	Background programme source, one input provided.
Pink Noise	Test programme source, one input provided.
Test Tone	Test programme source, one input provided.

ROUTING, PRIORITY AND MESSAGE STACKING

From these definitions a chart of functional and access requirements of each input was defined:

INPUT	FUNCTION	ACCESS
Police	Emergency	All Page
Security	Emergency/Staff Calls	All Page/Local All Pages/Selected Staff
Main Announcers	Race Information/Pages	Public or Staff By Language and/or Function
Administration	Pages	All Page/Local All Pages
Technical Office	Pages/Tests/Set-Up	Full Function
Betting Control	Betting Information	Betting Operations Office/Betting Booths/OCB
Betting Operations	Betting Information	Betting Booths/OCB
CCTV	Commentary/Programmes	Selected Public/Staff Zones by Function
Cassette Decks	Background Programme	Selected Public/Staff Areas
CD Player	Background Programme	Selected Public/Staff Areas
Tuner	Background Programme	Selected Public/Staff Areas
Pink Noise	Test/Set Up	Selected Public/Staff Areas
Test Tone	Test/Set Up	Selected Public/Staff Areas

Our analysis of these inputs and their requirements lead us to organize them into two basic types, continuous programme inputs and paging inputs. Continuous programme inputs were defined as those which featured comparatively long material and which typically had the lowest importance. Paging inputs were defined to be comparatively short messages with varying levels of importance.

This distinction was made to establish the basis for a priority system to allocate access to the output zones (loudspeakers). Since continuous programme inputs typically comprised low priority material it was deemed acceptable that these inputs could be over-ridden from time to time to accommodate pages, race information, or emergency messages. Further, continuous programme inputs were designed so as to be muted only in zones affected by a particular paging input (i.e. paging inputs would exercise layered priority over continuous programme inputs). Message lengths of continuous programme inputs are also such that message stacking would be both infeasible and undesirable.

Paging inputs are designed so that most routine announcements would be directed into message stacks. Race information, pages, promotional announcements, and routine crowd control messages are all designated as stacked messages. Emergency messages and special long announcements are assigned as direct announcements, bypassing the message stacks.

The assignment of inputs as either continuous programme or paging type is shown below:

INPUT TYPE	ASSIGNED INPUTS
Continuous	CCTV, Cassette Decks, CD Player, Tuner, Pink Noise, Test Tone.
Paging	Police, Security, Main Announcers, Administration, Technical Office, Betting Control, Betting Operations.

ROUTING, PRIORITY AND MESSAGE STACKING

Having defined how users (inputs) would be able to interface with the system, it was now possible to develop specification for the hardware which would handle these tasks. This system, called the Racecourse Routing System or RCRS, is illustrated in in a functional manner in Figure 1:

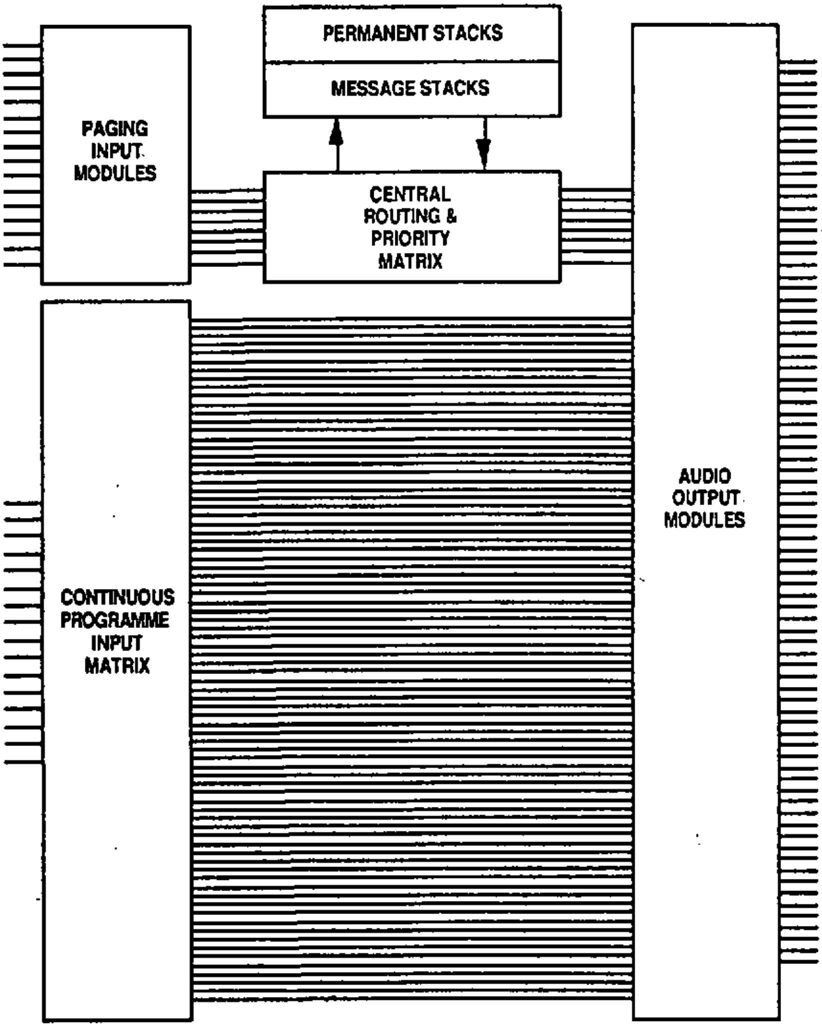

FIG. 1 — THE RACECOURSE ROUTING SYSTEM

ROUTING, PRIORITY AND MESSAGE STACKING

As is shown in Figure 1, the RCRS is composed of five component parts: paging input modules, continuous programme input matrix, central priority and routing matrix, message stacks, and audio output modules. These components are described below:

COMPONENT	FUNCTION
Paging Input Module	These modules function as the interface for all of the paging inputs, and include both an audio circuit for processing the incoming message audio and a control circuit for decoding the function buttons associated with each paging station. Capacity for 16 paging inputs is provided in the Macau systems.
Continuous Programme Matrix	This is a 16 input by 80 output matrix for routing the continuous programme inputs. The four CCTV programme inputs can be assigned to any of eight unique pre-set routing combinations via an eight button CCTV Routing Panel. The remaining continuous programme inputs are assigned through software.
Central Priority/Routing Matrix	This central matrix sorts and distributes audio from the paging input modules. Depending upon the type of message being input, the matrix distributes the audio either to the message stacks or to the audio output zones directly.
Message Stacks	These are the digital storage media which perform the stacking function. Two types are provided: message stacks, in which messages are stored, released in turn and then automatically cleared to make room for a new message; and permanent stacks, in which a message may be stored and replayed as often as the user requires.
Audio Output Modules	These units function as the interface to the rest of the audio systems. Each audio output module has two inputs, a background programme input which receives a feed from the continuous programme input matrix; and a paging input which receives a feed from the central priority and routing matrix. In normal operation, the audio output module passes the continuous programme signal to the output. When a page is directed to the module, the continuous programme is attenuated 20dB and the paging signal is passed to the output.

SYSTEM SET-UP

The specifications required that all adjustments to the system be made via software. This would allow the user to update the system configurations as time and changing circumstances dictated. On the paging stations, the users have been encouraged to think of the buttons in terms of functions, not areas served. A button might therefore be labelled "Race Essential Announcement" or "Promotional Message." Each button accesses a map containing the list of output zones to which the message should be directed. Maps can be changed at any time via software. Maps are determined by the course management; announcers therefore require very little training in the use of the systems.

The maps associated with the paging function buttons may be unique for each paging station. If desired though, the maps for the same function buttons on two different paging stations may overlap or even be identical. This allows the users to define certain areas as multi-lingual.

Continuous program inputs are also controlled via software. As described above, the CCTV programme inputs are controlled by a special Routing Panel with eight buttons. Each button accesses four maps, one for each language input. A lock-out function prevents more than one language being directed to any particular output. Once again these buttons are designated by function, so that CCTV audio is routed throughout the course on the basis of the type of programme then in progress. Other continuous programme inputs (CD Player and the like) have their routing determined in the software interface; these inputs are not affected by the CCTV Routing Panel.

SYSTEM OPERATION

The systems in the Macau Jockey Club were commissioned for their first use in September, 1989. Completed in near record time (the contracts for the installation were not signed until June), the systems have already demonstrated their effectiveness to racecourse officials and management.

The message stacking system has borne out our theory that high instantaneous access is the key to fostering free and unfettered access to large distributed audio systems. The users also appreciate the utility of a by-product of the stack systems, namely the permanent stacks. A series of permanent messages are presently being recorded for the Macau course. Some will concern essential race messages, such as the announcement of objections being lodged in a race, while others may be purely promotional such as a reminder that the time period for placing a particular form of multi-race bet is about to expire.

The software interface allows users to quickly and efficiently change the routing of languages throughout the course. As punter demographics change, racecourse officials may easily keep pace, insuring that patrons receive programmes in the proper language. The software interface also centralizes the decision-making process as it relates to the routing of message types. The decision to route a particular type of message to particular areas is therefore made by racecourse management — in advance — not by a harried announcer in the tense atmosphere of a race meeting. Routing errors are thereby avoided as much as possible.

Officials in Macau are only now awakening to the possibilities of generating additional revenues through creative programming of the audio systems. In the coming months, we expect that a full-fledged marketing program will be launched to take advantage of this potential.