US009270615B2

(12) **United States Patent**
Dupuis et al.

(10) **Patent No.: US 9,270,615 B2**
(45) **Date of Patent: Feb. 23, 2016**

(54) **METHOD AND TOOL FOR AUTOMATICALLY GENERATING A LIMITED SET OF SPECTRUM AND SERVICE PROFILES**

(75) Inventors: **Nicolas Dupuis**, Chaudfontaine (BE); **Benoit Drooghaag**, Ophain-Bois-Seigneur-Isaac (BE)

(73) Assignee: **Alcatel Lucent**, Boulogne-Billancourt (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 162 days.

(21) Appl. No.: **14/005,358**

(22) PCT Filed: **Apr. 3, 2012**

(86) PCT No.: **PCT/EP2012/056074**
§ 371 (c)(1), (2), (4) Date: **Oct. 7, 2013**

(87) PCT Pub. No.: **WO2012/136656**
PCT Pub. Date: **Oct. 11, 2012**

(65) **Prior Publication Data**

US 2014/0022927 A1 Jan. 23, 2014

(30) **Foreign Application Priority Data**

Apr. 8, 2011 (EP) 11305414

(51) **Int. Cl.**
G01R 31/08 (2006.01)
G06F 11/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 47/808*** (2013.01); ***H04L 41/142*** (2013.01); ***H04L 43/045*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 41/142; H04L 47/808; H04L 43/045
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,385,225	B1 *	2/2013	Downey	370/252
2008/0219290	A1 *	9/2008	Cioffi et al.	370/465

(Continued)

FOREIGN PATENT DOCUMENTS

EP	1995942	A1	11/2008
EP	2073439	A1	6/2009
EP	2107734	A1	10/2009

OTHER PUBLICATIONS

Maes et al., Maximizing Digital Subscriber Line Performance, Bell Labs Technical Journal 13, vol. 1, Mar. 21, 2008, pp. 105-115.

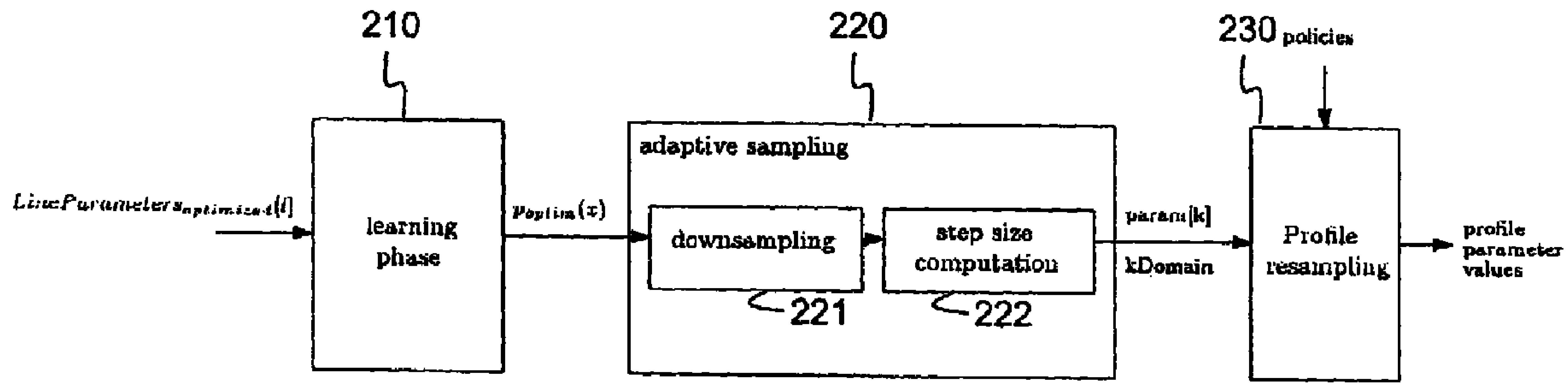
(Continued)

Primary Examiner — Lonnie Sweet
(74) *Attorney, Agent, or Firm* — Harnes, Dickey & Pierce, P.L.C.

(57) **ABSTRACT**

A method for automatically generating a limited set of spectrum and service profiles for use in an operator's telecommunication network includes collecting physical layer parameter values for individual lines, determining a set of optimized parameter values for each one of the individual lines, estimating a probability density function for each optimized parameter based on optimized parameter values for multiples lines, sampling the probability density function for each optimized parameter and selecting and combining according to parameter and profile policies a set of optimized parameter values to generate the limited set of spectrum and service profiles.

6 Claims, 6 Drawing Sheets



(51) **Int. Cl.**

G08C 15/00	(2006.01)
H04J 1/16	(2006.01)
H04J 3/14	(2006.01)
H04L 12/927	(2013.01)
H04L 12/24	(2006.01)
H04L 12/26	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0292021 A1 11/2008 Lv et al.
2010/0293274 A1 11/2010 Everett et al.
2011/0019575 A1 1/2011 Croot et al.

OTHER PUBLICATIONS

Written Opinion of the International Searching Authority PCT/ISA/237 for International Application No. PCT/EP2012/056074.

International Search Report PCT/ISA/210 for International Application No. PCT/EP2012/056074 Dated Apr. 27, 2012.

* cited by examiner

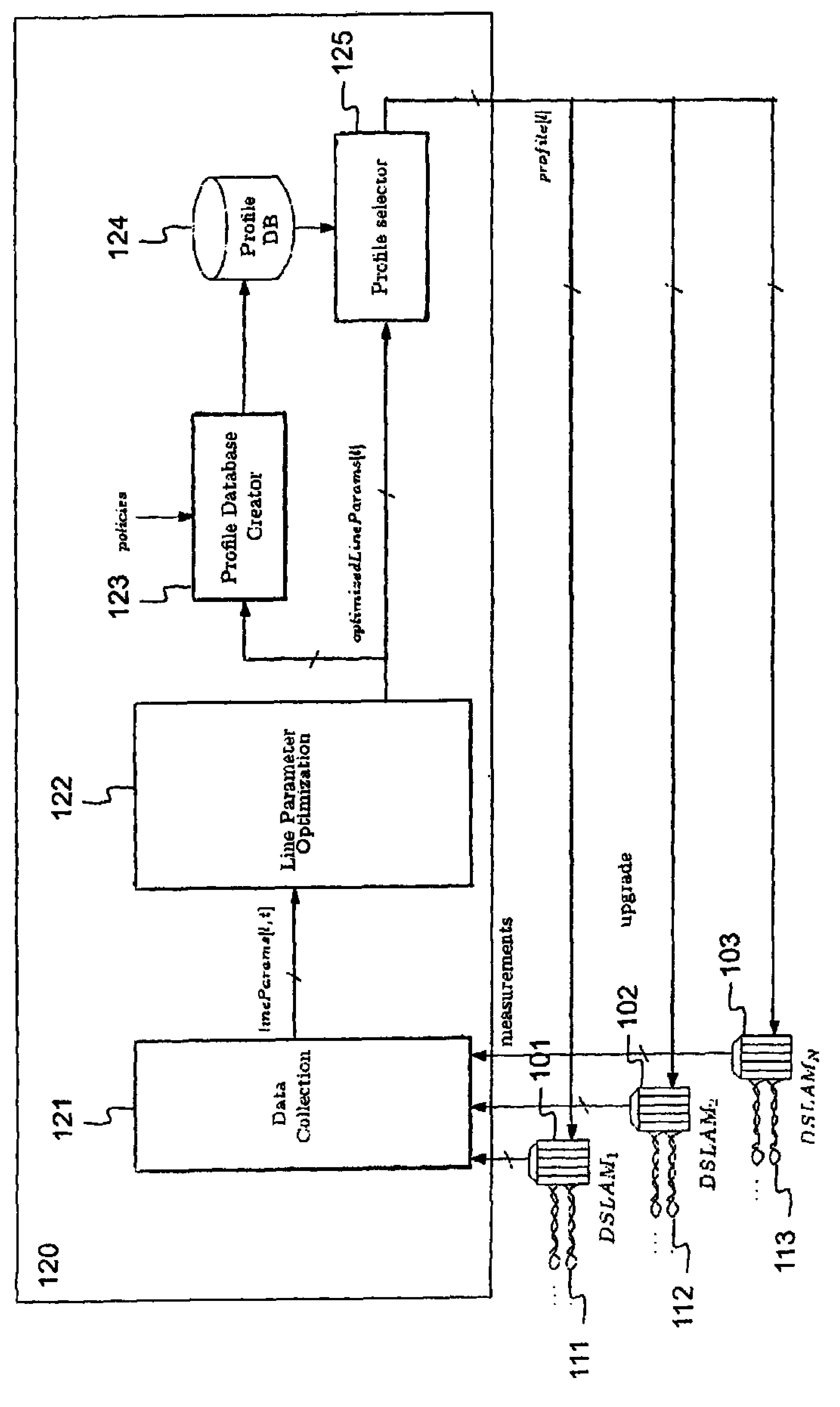

120
121
Data Collection
lineParams[l,t]
122
Line Parameter Optimization
optimizedLineParams[l]
123
policies
Profile Database Creator
124
Profile DB
125
Profile selector
profile[l]
measurements
upgrade
101
102
103
DSLAM$_1$
DSLAM$_2$
DSLAM$_N$
111
112
113

Fig. 1

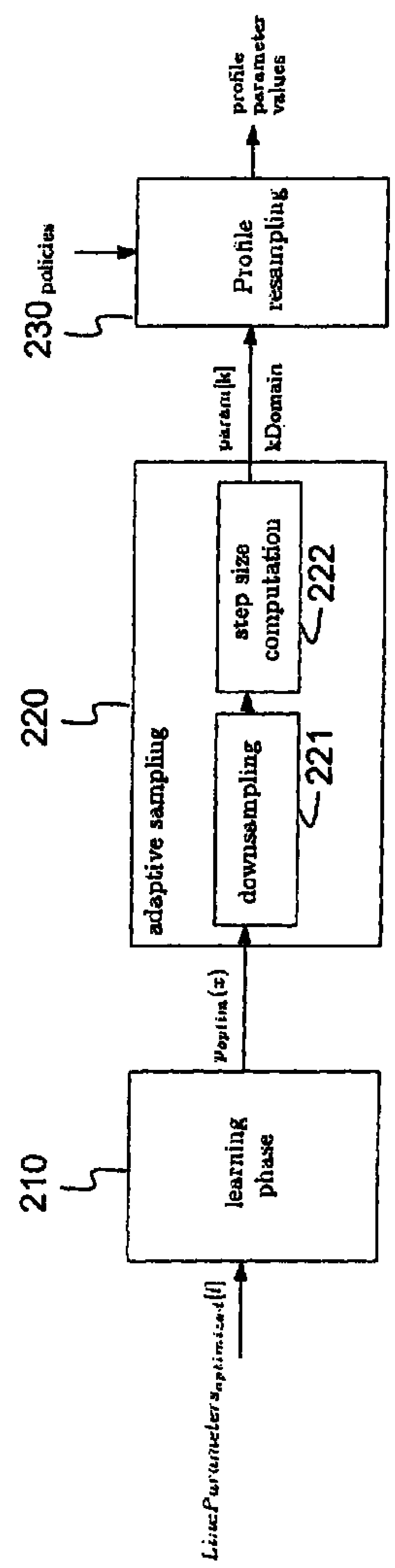

profile
parameter
values
policies
230
Profile
resampling
param[k]
kDomain
220
adaptive sampling
step size
computation
222
downsampling
221
210
learning
phase

Fig. 2

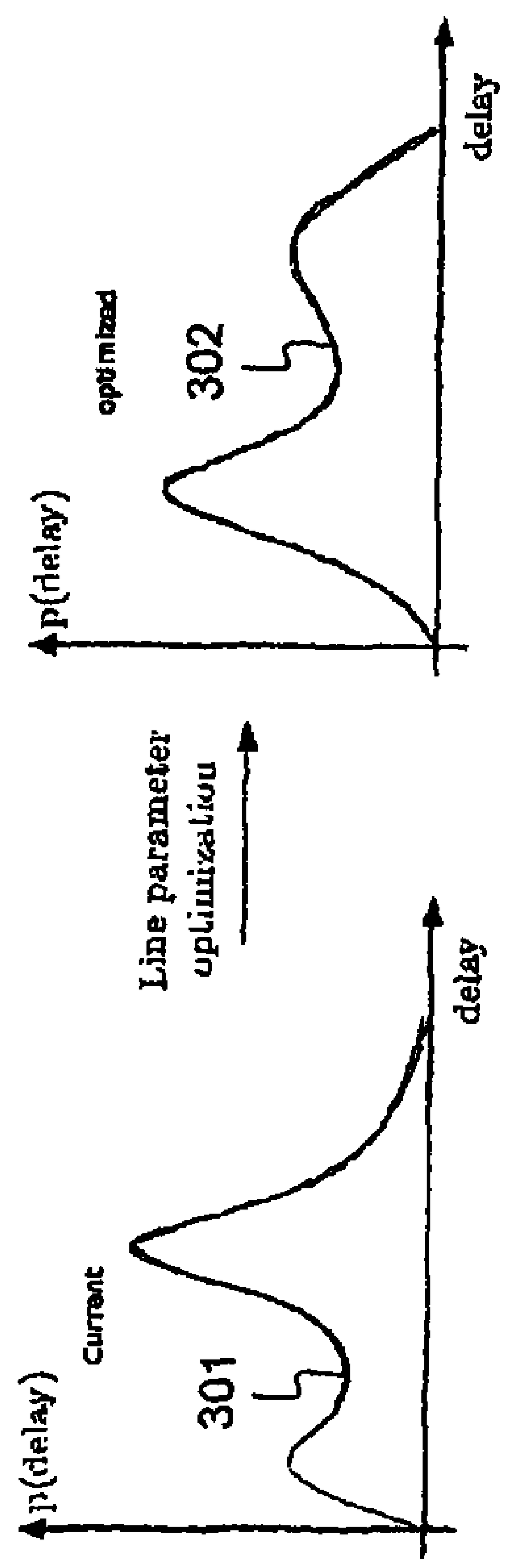

p(delay)
Current
301
delay
Line parameter
optimization
p(delay)
optimized
302
delay

Fig. 3

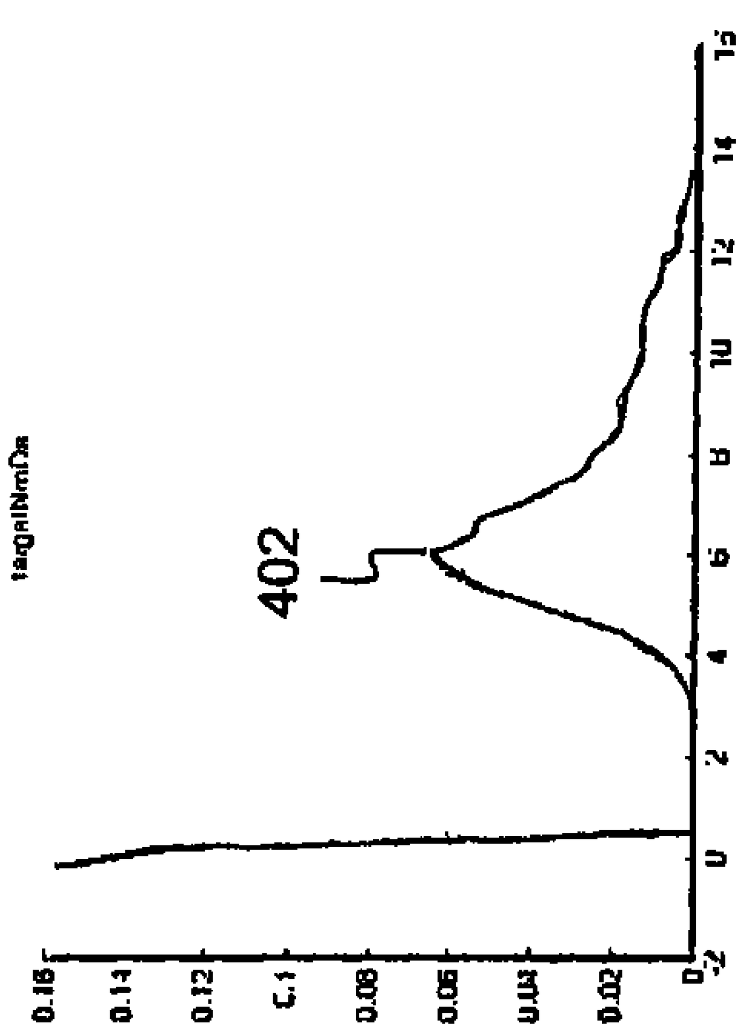


Fig. 4B

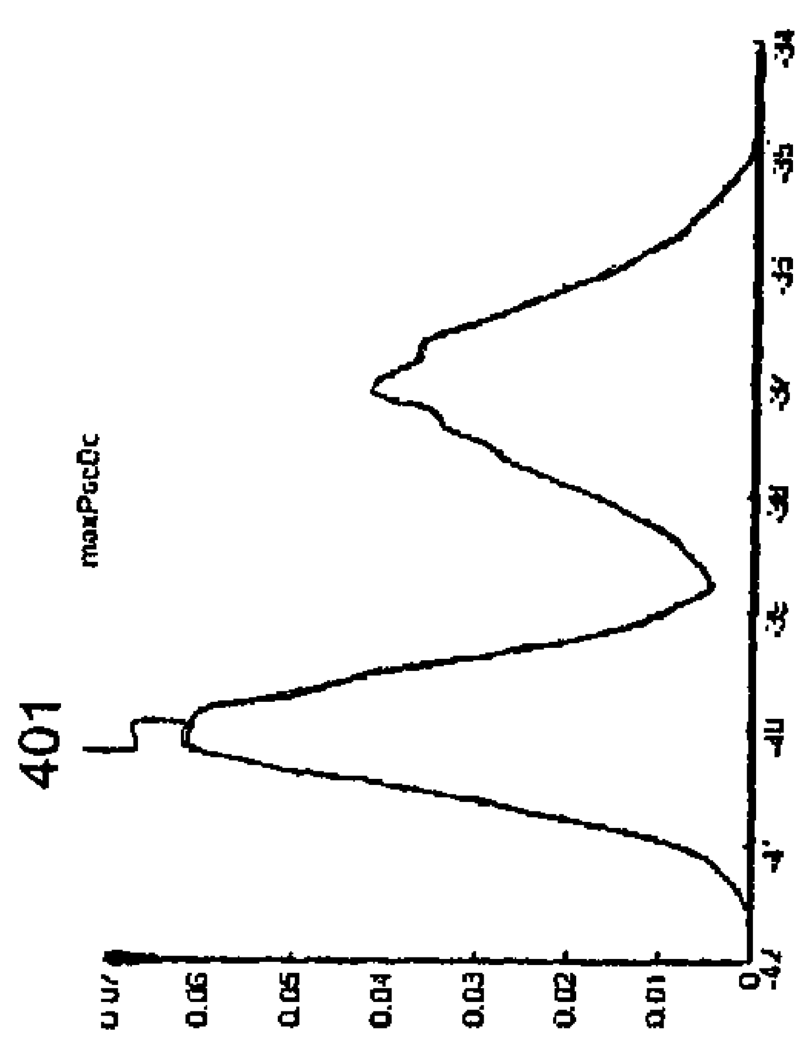


Fig. 4A

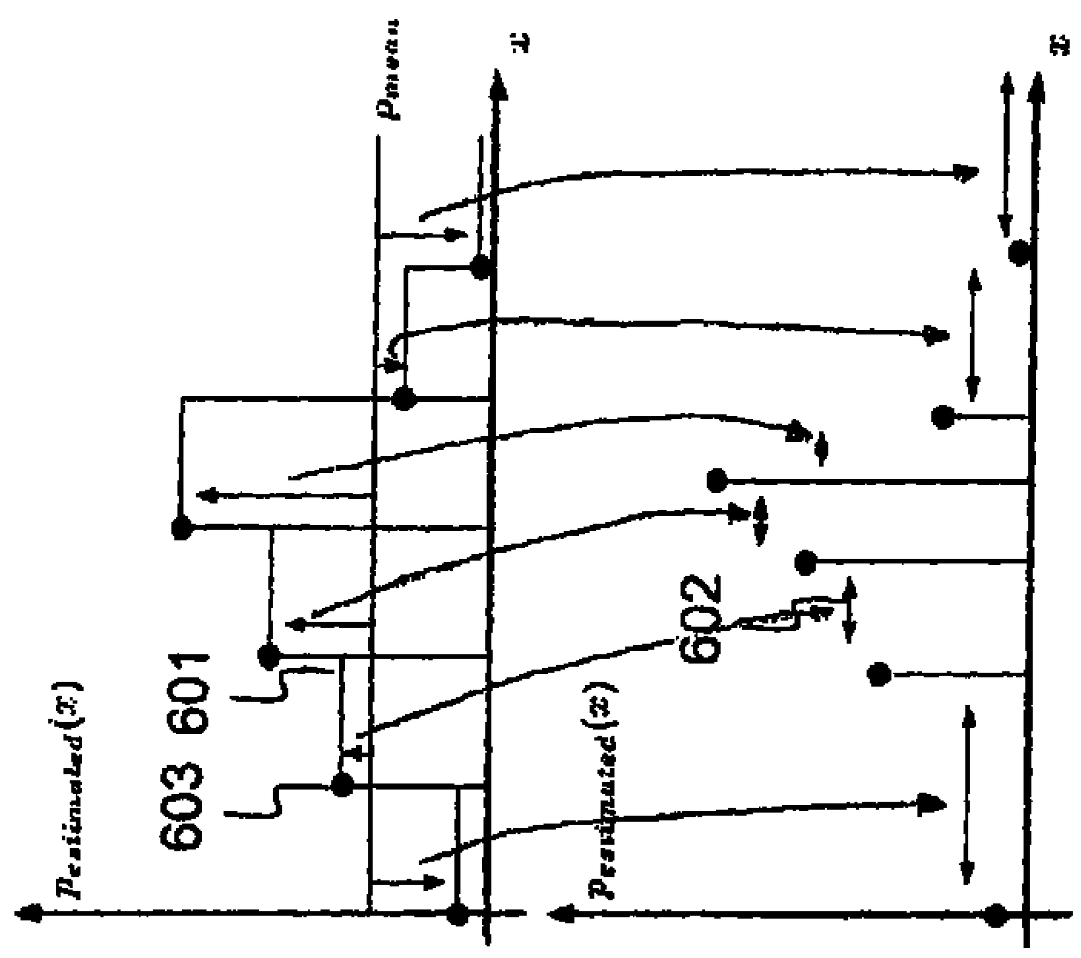


Fig. 6

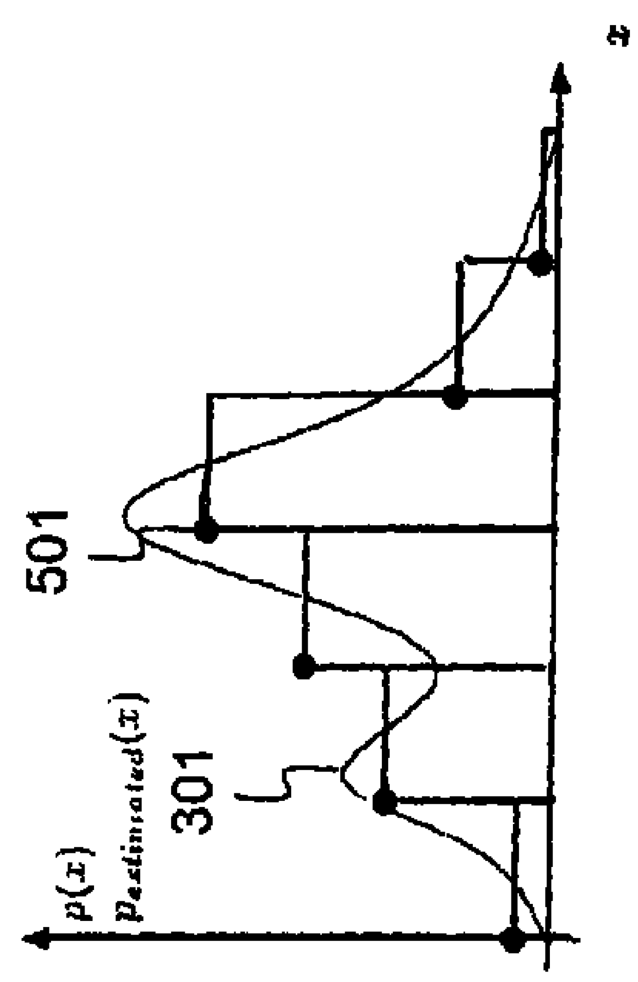


Fig. 5

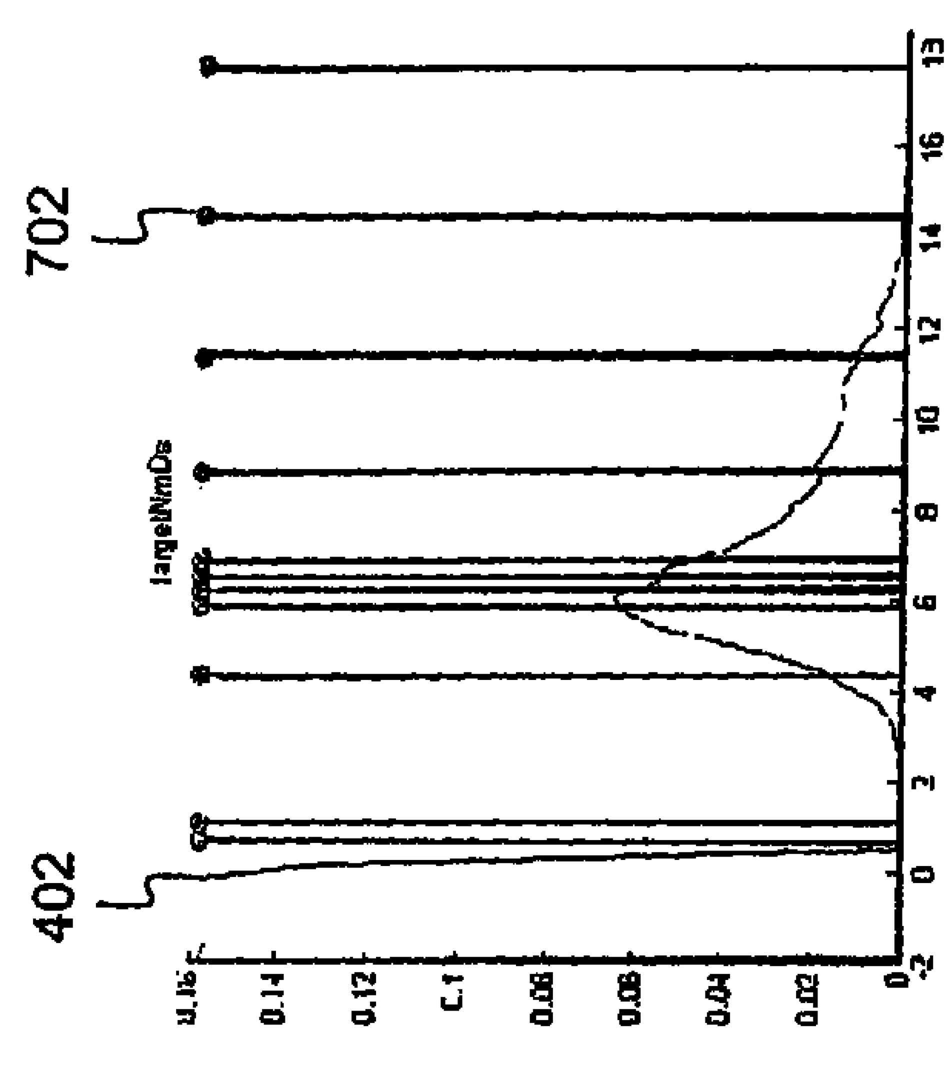


Fig. 7B

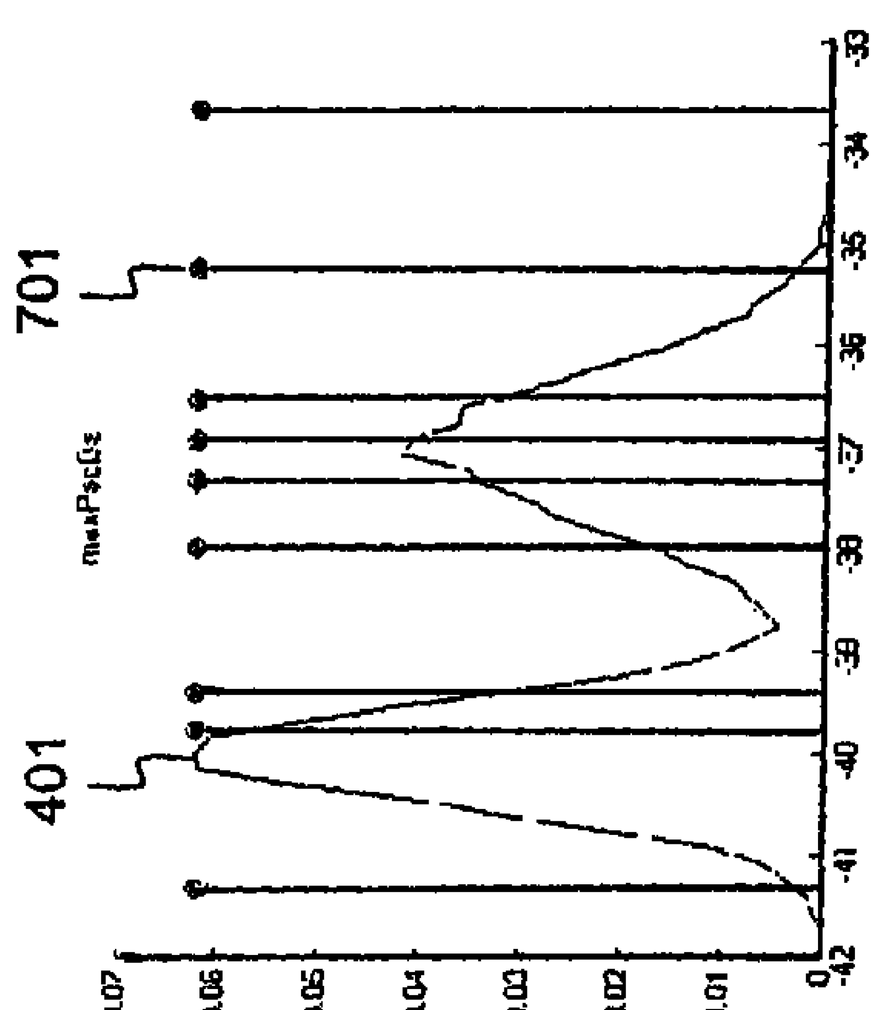


Fig. 7A

METHOD AND TOOL FOR AUTOMATICALLY GENERATING A LIMITED SET OF SPECTRUM AND SERVICE PROFILES

This application is the national phase under 35 U.S.C. §371 of PCT International Application No. PCT/EP2012/056074 which has an International filing date of Apr. 3, 2012, which claims priority to European patent application number EP 11305414.2 filed Apr. 8, 2011; the entire contents of each of which are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention generally relates to generating spectrum and service profiles for a telecom operator's network, e.g. a Digital Subscriber Line (DSL) network. Such spectrum and service profile defines the state of the physical links in terms of performances, quality of service, robustness, etc. through a number of parameters such as the maximum bit rate, the target noise margin, the maximum delay allowed and the maximum power spectral density (PSD). The use of a certain spectrum and service profile compared to another one allows preferring one strategic choice versus another, e.g. enhancing stability in trade off against offered bit rate. The invention in particular concerns the automated generation of such spectrum and service profiles.

BACKGROUND OF THE INVENTION

At present, spectrum and service profiles are generated manually, typically in close collaboration with the operator. The operator's network is investigated for potential sources of performance limitations and for physical layer parameter values that are regularly used in the network. This information is interpreted manually and used to determine in close collaboration with the operator a consistent set of spectrum and service profiles that enables to face the main issues and improve the overall performance.

As a result of uprising new services such as IPTV (Internet Protocol Television), VoD (Video on Demand), and Triple Play services, the management of system performances and customer support become more demanding. Often, the physical layer that transports the information over wired lines up to the end user, is the bottle neck for quality of service. Operators are using a network analyzer to remotely detect and diagnose physical layer problems, and eventually take action to improve performance.

Such network analyzer, like the Alcatel Lucent 5530 NA, typically features a Dynamic Line Manager (DLM) that monitors the line performance and takes action in order to improve performance of a line. The DLM thereto uses the spectrum and service profiles manually generated with collaboration of the operator. In a DSL network for instance, a set of such manually defined spectrum and service profiles is available from a server or in the DSLAMs. The set of spectrum and service profiles is typically constructed offline and stored on a server, e.g. the Dynamic Line Management (DLM) server. After construction, for simplicity of maintenance, the set of profiles is usually pushed into each DSLAM of the network. The set of spectrum and service profiles is consequently the same for all equipment in the DSL network, constructed to face most of the common situations, and consequently used to manage the entire DSL network. The DLM switches between the profiles and chooses the most suitable one for each line.

The human effort in the known method for generating spectrum and service profiles is tremendous: a detailed interpretation and analysis of the existing network data is required, a suitable set of parameter values has to be identified, and a set of spectrum and service profiles has to be determined in collaboration with the operator. As a consequence, the effort and cost for operators and network management system vendors is high.

An additional drawback of the known, manual method for generating spectrum and service profiles is that it tends to result in sub-optimal behaviour because the manual method inherently lacks objectivity. The set of spectrum and service profiles in other words is insufficiently accurate.

It is an objective of the present invention to disclose a method and tool for generating spectrum and service profiles that overcomes the above mentioned drawbacks of the known, manual method. More particularly, it is an objective to teach generating spectrum and service profiles in a manner that requires less or no human effort, that is less costly and time consuming for operators and network management system vendors, and that generates more optimal spectrum and service profiles.

SUMMARY OF THE INVENTION

According to the present invention, the above defined objective is realized by a method for automatically generating a limited set of spectrum and service profiles for use in an operator's telecommunication network, the method comprising the steps of:

- collecting physical layer parameter values for individual lines;
- determining a set of optimized parameter values for each one of the individual lines;
- estimating a probability density function for each optimized parameter based on optimized parameter values for multiple lines;
- sampling the probability density function for each optimized parameter; and
- selecting and combining according to parameter and profile policies a set of optimized parameter values thereby generating the limited set of spectrum and service profiles.

Thus, the invention basically consists in a method that automatically generates a set of optimal spectrum and service profiles by using collected field data from the operator's network. The method consists of a learning phase wherein the probability density functions are estimated for each optimized parameter. Secondly, the parameter value domain is discretized through sampling. In the last step, a set of parameter values is returned that can be embedded into spectrum and service profiles. These parameter values are selected according to parameter policies, e.g. range granularity, etc., as well as profile policies, e.g. the maximum number of profiles, the minimum variation between profiles, etc. The method according to the invention is fully automated. This allows building a more accurate and therefore more optimal set of spectrum and service profiles based on statistics on optimal parameter values. As a result of the automated nature, there is no need for intensive human support in the creation of a set of spectrum and service profiles, which saves effort, time and money.

Optionally, as defined by claim **2**, estimating the probability density function for each optimized parameter comprises determining histograms for each optimized parameter.

Indeed, there exist several methods to achieve estimating the probability density functions of optimized parameters, but histograms give already relevant results.

Also optionally, as defined by claim **3**, sampling the probability density function for each optimized parameter comprises down-sampling the probability density function for each optimized parameter to thereby restrict the number of spectrum and service profiles in the limited set.

Indeed, probability density functions are usually highly sampled for accuracy reasons. Since the current invention aims at restricting the number of output spectrum and service profiles, down-sampling of the distribution functions is performed.

Further optionally, as defined by claim, the sampling step used for down-sampling is determined by a deviation between a current probability density value and a mean probability density value.

Thus, the sampling step between two samples of the probability density functions may be determined in function of the deviation between the current probability density value and the mean probability density value. The sign of the deviation determines if the step size is smaller or larger than the one used in uniform sampling. The amplitude determines the deviation with respect to the uniform one.

According to a further optional aspect defined by claim **5**, selecting and combining a set of optimized parameter values may comprise taking all possible cross-combinations of optimized parameter value samples.

Indeed, the outputs of the sampling step may be expressed as vectors containing the different possible values. Profiles are then generated by taking all possible cross-combinations of parameter values.

As is indicated by claim **6**, a spectrum and service profile may comprise one or more of the following parameters:

a target noise margin;

a maximum allowable delay;

a maximum bit rate; and

a maximum power spectral density.

It is noticed that the above list is not exhaustive and other parameters could become managed as well, for example the minimum bit rate. As will be appreciated by the skilled person, applicability of the present invention is not limited to a particular choice or list of spectrum and service profile parameters.

As is indicated by claim **7**, the physical layer parameter values may comprise one or more of the following:

the loop attenuation;

the background noise power;

the impulse noise level; and

the transmitted power level

Also this list of physical layer parameters is non-exhaustive.

As is indicated by claim **8**, the parameter and profile policies may comprise one or more of the following:

a range of parameter values (parameter policy);

a granularity for parameter values (parameter policy);

a maximum number of profiles (profile policy); and

a minimum variation between profiles (profile policy).

The list of parameter and profile policies is also non-exhaustive.

In addition to a method for automatically generating a limited set of spectrum and service profiles as defined by claim **1**, the current invention also concerns a corresponding tool for automatically generating a limited set of spectrum and service profiles for use in an operator's telecommunication network, the tool being defined by claim **9** and comprising:

means for receiving physical layer parameter values for individual lines;

means for determining a set of optimized parameter values for each one of the individual lines;

means for estimating a probability density function for each optimized parameter based on optimized parameter values for multiple lines;

means for sampling the probability density function for each optimized parameter; and

means for selecting and combining according to parameter and profile policies a set of optimized parameter values thereby generating the limited set of spectrum and service profiles.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** represents a functional block diagram of a Dynamic Line Manager (DLM or **120**) containing an embodiment **123** of the tool for generating spectrum and service profiles according to the current invention;

FIG. **2** represents a diagram illustrating an embodiment of the method for generating spectrum and service profiles according to the present invention, executed by the profile database creator **123** of FIG. **1**;

FIG. **3** illustrates the effect of line parameter optimization on probability density functions in an embodiment of the method according to the invention;

FIG. **4**A and FIG. **4**B illustrate the step of estimating probability density functions for two parameters in an embodiment of the method according to the present invention;

FIG. **5** illustrates the step of sampling the probability density functions in an embodiment of the method according to the present invention, using uniform sampling;

FIG. **6** illustrates the step of sampling the probability density functions in an embodiment of the method according to the present invention, using adaptive sampling; and

FIG. **7**A and FIG. **7**B illustrate adaptive sampling applied to the probability density functions of FIG. **4**A and FIG. **4**B.

DETAILED DESCRIPTION OF EMBODIMENT(S)

FIG. **1** illustrates the optimization process performed by the Dynamic Line Manager **120** to enhance the performance of the lines of an entire DSL network represented in FIG. **1** by DSLAMs **101**, **102** and **103**, and DSL lines **111**, **112** and **113**.

When using a network analyzer it is possible to massively collect physical data from the DSLAMs spread in the entire operator's DSL network. By monitoring the physical state of individual DSL lines, line parameter values like the transmitted power, the loop attenuation, the background noise power and the impulse noise level can be collected. Obviously, the just mentioned line parameters are exemplary as more or other parameters could be monitored. These measured data are collected by or handed over to the data collection unit **121** in DLM **120**.

The line parameter optimization unit **122** thereupon determines the optimal value of several modem parameters, for example the maximum PSD downstream, the actual delay downstream, the maximum bit rate downstream and the target noise margin downstream, for given individual lines in the operator's network.

In summary, it is assumed that a collection of physical layer parameters, such as the loop attenuation, transmitted power, etc., is measured, and some line state estimators, such as background noise estimators or impulse noise estimators, have been performed. According to these values, an optimized set of modem parameter values is returned for a given individual line. This optimization process for physical layer parameter values is repeated over all individual lines of the entire network, as a result of which statistical techniques become relevant to learn the most probable values present in the network and the distributions of optimal parameter values.

These statistical techniques are applied by the profile database generator **123** which processes the optimal parameter values from multiple lines, generates probability density functions and selects parameter values for a limited set of profiles. The profile database creator **123** in other words represents an embodiment of the tool for automatically generating a limited set of optimized spectrum and service profiles in accordance with the principles of the current invention.

The generated spectrum and service profiles are stored in a profile database **124** and a profile selector **125** selects for each line of an entire network or part of a network the most suitable spectrum and service profile(s) from the limited set stored in the database **124** corresponding to the optimal parameters.

FIG. **2** shows in more detail the different steps in the automatic profile database creation process that is applied by profile database creator **123**. In the learning phase **210**, the profile database generator **123** generates probability density functions $p_{optim}(x)$ from the optimized parameter values for individual lines, $LineParameters_{optimized}[1]$. An estimation of the probability density functions $p_{optim}(x)$, is carried out for each optimized parameter. There are several possible methods to achieve this task but histograms give already relevant results. In the adaptive sampling phase **220**, these probability density functions $p_{optim}(x)$ are downsampled in step **221** and the sample step size is adaptively adjusted in step **222**. At last, parameter policies and profile policies are used in the profile resampling phase **230** to select the parameter values that will be combined to form a limited set of spectrum and service profiles.

The effect of the line parameter optimization **122** on the probability density of a given parameter, e.g. the delay, is illustrated by FIG. **3**. Herein, the change of values in the probability densities of the delay, from the actual modem parameters **301** to the optimized ones **302**, is shown. The adaptive building of optimized profiles will be performed directly on such probability densities of optimized parameter values.

The purpose of the method according to the present invention is to create a set of spectrum and service profiles that matches as much as possible the optimized distributions, e.g. **302**, in order to provide the most suitable sampling of them. Since the number of profiles which can be entered in DSLAM's is limited and since these profiles must be easily understood and maintained, only a limited number of profiles must be used.

Choosing a uniform sampling between profile parameter values usually does not allow choosing the best-fit profile for a given line, and does not tend to reach a limited, optimal set of profiles for the entire network. At network-wide scale, there will be more lines closer to optimal profiles as a result of the current invention, delivering an overall benefit.

FIG. **4**A shows the probability density function **401** or maxPsdDs obtained for the optimized maximum Power Spectral Density values of multiple lines in the DSL network of FIG. **1**. Similarly, FIG. **4**B shows the probability density function **402** or targetNoiseMarginDs obtained for the optimized target noise margin values values of multiple lines in the DS network of FIG. **1**. Choosing a uniform sampling for the optimal maximum PSD downstream and the optimal target noise margin, for example:

optimal maxPsdDs=[−42 −41 −40 −39 −38 −37 −36]; and
optimal targetNmDs=[1 3 5 7 9 11],

is not the most advantageous. Almost no maxPsdDs value of −39 dBm/Hz are optimal for the current field operator, neither target noise margin values of 1 dB. By contrast, 6 dB noise margins are usually optimal, as seen in the probability density function **402**. Not providing the possibility to use such values would inevitably imply a lack of optimality. Downsampling a probability density function with uniform sampling step is illustrated by FIG. **5** for the probability density function **301**.

In the sampling phase **220** of the embodiment illustrated by FIG. **2**, the computation of an adaptive sampling is done, more precisely the discretization of the parameter value domain using a continuously adjustable sampling rate. This can be achieved by a down-sampling step **221** followed by a step size computation **222**. As probability density functions are usually highly sampled for accuracy reasons, down-sampling of such distributions enables to limit the number of output profiles.

In step **222**, the sampling step size between two samples is determined by the deviation between the current probability density value with respect to the mean probability density value p_{mean}. The sign of the deviation determines if the step size is smaller or larger than the one used in uniform sampling. The amplitude determines the deviation with respect to the uniform one. This is illustrated by FIG. **6** where the sampling step **601** in the uniform sampling is for instance shrunk to the sampling step **602** as a result of a corresponding deviation of the current probability density value **603** from the mean probability density value p_{mean}.

FIG. **7**A illustrates adaptive sampling **701** for the maxPsdDs probability density function **401**. FIG. **7**B illustrates adaptive sampling **702** for the targetNoiseMarginDs probability density function **402**.

In this profile resampling phase **230**, a set of parameter values that can be embedded into profiles is selected. The profile database creator **123** thereto uses parameter policies, e.g. the range, granularity, etc., as well as profile policies, e.g. the maximum number of profiles, the minimum variation between profiles, etc.

The outputs of the resampling phase **230** can be expressed as vectors containing the different possible values. The profiles are thus generated by taking all the possible cross-combinations between the value, e.g.:

maxPsdDs=[−42 −39 −36];
actualDelayDs=[3.5 6 6.5 8 10.5];
maxBitrateDs=[6000 7500 8000 8500 9500]; and
targetNmDs=[1 6.5 11.5].

Although the present invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments, and that the present invention may be embodied with various changes and modifications without departing from the scope thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. In other words, it is contemplated to cover any and all modifications, variations or equivalents that fall within the scope of the basic underlying principles and whose essential attributes are claimed in this patent application. It will furthermore be understood by the reader of this patent application that the words "comprising" or "comprise" do not exclude other elements or steps, that the words "a" or "an" do not exclude a plurality, and that a single element, such as a computer system, a processor, or another integrated unit may fulfil the functions of several means recited in the claims. Any reference signs in the claims shall not be construed as limiting the respective claims concerned. The terms "first", "second", third", "a", "b", "c", and the like, when used in the description or in the claims are introduced to distinguish between similar elements or steps and are not necessarily describing a sequential or chronological order. Similarly, the terms "top", "bottom", "over", "under", and the like are introduced for descriptive purposes and not necessarily to denote relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and embodiments of the invention are capable of operating according to the present invention in other sequences, or in orientations different from the one(s) described or illustrated above.

The invention claimed is:

1. A method for automatically generating a limited set of spectrum and service profiles for use in an operator's telecommunication network, said limited set of spectrum and service profiles being associated with a plurality of performance link parameters including at least one of a target noise margin, a maximum allowable delay, a maximum bit rate, and a maximum power spectral density, said method comprising:

collecting, by a dynamic line manager, physical layer parameter values for a plurality of individual lines, said physical layer parameter values including one or more of a loop attenuation, a background noise power, an impulse noise level and a transmitted power level;

determining, by the dynamic line manager, a set of parameter values for each of the plurality of individual lines from said physical layer parameter values;

generating, by the dynamic line manager, a probability density function for each of the set of parameter values based on the sets of parameter values for the plurality of individual lines;

down-sampling, by the dynamic line manager, said probability density function for each of the set of parameter values to restrict a number of spectrum and service profiles in said limited set; and

selecting and combining according to parameter and profile policies, by the dynamic line manager, a limited set of parameter values; and

generating said limited set of spectrum and service profiles by cross-combining said limited set of parameter values.

2. The method according to claim **1**, wherein the generating said probability density function for each of the set of parameter values comprises:

determining histograms for each of the set of parameter values .

3. The method according to claim **1**, wherein a sampling step used for said down-sampling is determined based on a deviation between a current probability density value and a mean probability density value.

4. The method according to claim **1**, wherein said selecting and combining a limited set of parameter values comprises:

examining all possible cross-combinations of parameter value samples.

5. The method according to claim **1**, wherein said parameter and profile policies comprise one or more of,

a range of parameter values,

a granularity for parameter values,

a maximum number of profiles, and

a minimum variation between profiles.

6. An apparatus for automatically generating a limited set of spectrum and service profiles for use in an operator's telecommunication network, said limited set of spectrum and service profiles being associated with a plurality of performance link parameters including at least one of a target noise margin, a maximum allowable delay, a maximum bit rate, and a maximum power spectral density, said apparatus comprising:

a memory having computer readable instructions stored thereon and

a processor, which when executing the instructions, is configured to:

collect physical layer parameter values for a plurality of individual lines, said physical layer parameter values including one or more of a loop attenuation, a background noise power, an impulse noise level and a transmitted power level;

determine a set of parameter values for each of the plurality of individual lines from said physical layer parameter values;

generate a probability density function for each of the set of parameter values based on the sets of parameter values for the plurality of individual lines;

down-sample said probability density function for each of the set of parameter values to restrict a number of spectrum and service profiles in said limited set; and

select and combine according to parameter and profile policies a limited set of parameter values; and

generate said limited set of spectrum and service profiles by cross-combining said limited set of parameter values.

* * * * *