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(54) **DISTRIBUTED PCE-BASED SYSTEM AND ARCHITECTURE IN A MULTI-LAYER NETWORK**

VERTEILTES SYSTEM UND ARCHITEKTUR AUF PCE-BASIS IN EINEM MEHRSCHICHT-NETZWERK

SYSTÈME ET ARCHITECTURE DISTRIBUÉS À BASE D'ÉLÉMENTS DE CALCUL DE TRAJETS DANS UN RÉSEAU MULTICOUCHE

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(73) Proprietor: **Huawei Technologies Co., Ltd.**
Longgang District
Shenzhen, Guangdong 518129 (CN)

(72) Inventor: **LEE, Young**
Plano, Texas 75075 (US)

(74) Representative: **Körber, Martin Hans**
Mitscherlich PartmbB
Patent- und Rechtsanwälte
Sonnenstrasse 33
80331 München (DE)

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Description

Field of the Invention

[0001] The present invention relates generally to telecommunications, and more particularly, to a distributed Path Computation Element based (PCE-based) system and architecture in a multi-layer network.

Background of the Invention

[0002] A PCE is an entity that is capable of computing a network path or route based on a network topology, and applying computational constraints to the computation. The capability of a PCE to compute different types of paths allows a PCE to provide traffic engineering functions.

[0003] Constraint-based path computation is a fundamental building block for traffic engineering networks. However, in these kinds of networks, path computation is complex, and may require special computational components and cooperation between different network domains.

[0004] A PCE-based network architecture defines PCEs to perform computations of a multi-layer path, and to take constraints into consideration. A multi-layer network may be considered as distinct path computation regions within a PCE domain. Therefore, a PCE-based architecture is used to allow path computation from one layer network region, across the multi-layer network, to another layer network region. A PCE may be placed on a single network node with high processing capabilities, or several PCEs may be deployed on nodes across a network.

[0005] A distributed PCE model may refer to a domain or network that may include multiple PCEs, and computations of paths are shared among the PCEs. A given path may in turn be computed by a single, or multiple PCEs. A PCE agent may be linked to a particular PCE or may be able to choose freely among several PCEs.

[0006] To address the complexity of path computations in multi-layer networks, there is a need for a PCE-based system in multi-layer networks, which provides efficient, correct and optimal path computations.

[0007] European patent application EP 1 460 808 A2 provides a method for implementing an inter-domain constraint-based shortest path first technique for supporting hierarchical routing in interconnected multi-domain OTNs.

[0008] Eiji Oki et al., "Framework for PCE-Based Inter-Layer MPLS and GMPLS Traffic Engeneering; draft-ietf-pce-inter-layer-frwk-O 1.txt", IETF Draft, June 2006, pages 1-15, XP015045437, Internet Engeneering Task Force, IETF, Geneva, CH describes a framework for the PCE-based path computation architecture tto inter-layer MPLS and GMPLS traffic engineering. The document provides suggestions for the deployment of PCE in support of multi-layer networks. The document alos describes network models where PCE performs inter-layer traffic engineering and the relationship between PCE and a functional component called Virtual Network Topology Manager (VNTM).

Summary of the Invention

[0009] The present invention provides a distributed PCE-based system in a multi-layer network. The system includes at least one higher-layer PCE, adapted to compute packet layer Label Switched Paths (LSPs); at least one lower-layer PCE, adapted to compute optical layer LSPs responsive to a request of the at least one higher-layer PCE; at least one higher-layer Traffic Engineering Database (TED), adapted to provide all relevant Traffic Engineering (TE) link information to the at least one higher-layer PCE; at least one lower-layer TED, adapted to provide all relevant Traffic Engineering link information to the at least one lower-layer PCE; and at least one PCE Agent, adapted to interact with the at least one lower-layer PCE for optical LSP provisioning.

[0010] The distributed higher-layer and lower-layer PCEs, in the present invention, provide functions cooperatively for multi-layer path computations. The higher-layer and lower-layer TEDs provide TE link information to be able to compute multi-layer traffic engineering Label Switched Paths (LSPs), while maintaining layer-specific traffic engineered database in a distributed fashion.

[0011] The PCE Agent, in the present invention, is adapted to provide static optical layer path provisioning, and reconfiguration of optical layer LSPs in cooperation with the at least one lower-layer PCE.

[0012] The present invention provides a static optical layer path provisioning mode, to establish optical LSPs on a pre-establishment basis. In addition, the present invention provides a dynamic multi-layer path provisioning mode, to dynamically establish an LSP, with cooperation of higher-layer and lower-layer PCEs.

[0013] The following description and drawings set forth in detail a number of illustrative embodiments of the invention. These embodiments are indicative of but a few of the various ways in which the present invention may be utilized.

Brief Description of the Drawings

[0014] For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

Fig.1 depicts an embodiment of a distributed path computation element based multi-layer network architecture according to the present invention;

Fig.2 depicts an embodiment of a static optical layer path provisioning mode in an optical transport network layer according to the present invention;

Fig.3 depicts an embodiment of a dynamic multi-layer path provisioning mode according to the present invention; and

Fig.4 depicts an embodiment of a crankback hold-off mode according to the present invention.

Detailed Description of the Invention

[0015] The following discussion is presented to enable a person skilled in the art to make and use the invention.

[0016] Referring now to drawings, and initially to Fig. 1, an embodiment of a distributed PCE-based multi-layer network architecture 100 is illustrated according to the present invention. The Multi-Layer Network (MLN) PCE-based system 110 may be taken as an independent server (i.e., an external entity) from the perspective of other network nodes.

[0017] MLN PCE-based system 110 includes a PCE (Hi) 115 and a PCE (Lo) 116, distributed in a higher-layer and a lower-layer of a multi-layer network, respectively. PCE 115 and 116 function separately, but operate in a cooperative manner to provide multi-layer traffic engineered path computations. There may be multiple PCEs (Hi) and PCEs (Lo). Each PCE (Hi) may communicate with each PCE (Lo). PCE 115 may be seen as a client to PCE 116, PCE 116 provides a lower-layer path computation service responsive to a request of PCE 115.

[0018] PCE 116 may be used to compute optical layer Label Switched Paths (LSPs) (e.g., optical channel/Lambda layer), and PCE 115 may be used to compute packet layer LSPs (e.g., Internet Protocol/Multiprotocol Label Switching layer). PCE 115 and PCE 116 cooperate for an end-to-end multi-layer path computation. PCE 116 may provide pre-established Optical-LSP information upon a request of PCE 115, which is referred to as a Static Optical Layer Path Provisioning (SOLPP) Mode. PCE 116 may also provide dynamically a new light path computation upon a request of an Area Border Router (ABR), which is referred to as a Dynamic Multi-Layer Path Provisioning (DMLPP) Mode.

[0019] MLN PCE-based system 110 includes two layer specific TED for each layer: TED (Hi) 112 and TED (Lo) 114. TED 112 provides all relevant TE link information to PCE 115, and TED 114 provides all relevant TE link information to PCE 116. When there are multiple PCEs (Hi) and PCEs (Lo), each PCE (Hi) is connected to a TED (Hi), and each PCE (Lo) is connected to a TED (Lo).

[0020] PCE Agent 117 in MLN PCE-based system 110 is an enabler of MLN PCE-based system 110 performing many functions. PCE Agent 117 is basically a management component that interacts with PCE 116 for optical transport LSP provisioning.

[0021] PCE agent 117 may be any client application, requesting a path computation to being performed by a PCE. There are numbers of functions PCE Agent 117 may facilitate, in order to provide a complete solution in MLN Traffic Engineering. PCE Agent 117 plays a central role in MLN PCE-based system 110 providing a brain of the system.

[0022] In one embodiment, PCE Agent 117 may provide path provisioning of lower layer LSPs (i.e., Optical LSPs). PCE Agent 117 initiates LSP setup in a lower layer. This may be an off-line provisioning process that may be viewed as a part of a network planning function. Trigger for the path provisioning is not a dynamic trigger from a higher-layer. Trigger for the path provisioning may be driven by network planning. PCE Agent 117 may initiate a global concurrent path computation to PCE 116 using a traffic demand matrix.

[0023] In an alternative embodiment, PCE Agent 117 interacts with PCE 116 for computation of lower-layer LSPs. PCE Agent 117 plays as a Path Computation Client (PCC) to PCE 116 for lower-layer LSPs. In one embodiment, upon receipt of a traffic demand, PCE Agent 117 derives a point-to-point traffic matrix that will be an input to PCE 116. PCE Agent 117 may be adapted to formulate a global concurrent path computation request to PCE 116. PCE Agent 117 interacts with a PCE Policy Server 140 to derive all decision parameters required in a global concurrent path computation. The decision parameters may include global objective functions, or global constraints, etc.

[0024] Alternatively, PCE Agent 117 may have intelligence to perform iterative path computation when an initial global concurrent path computation fails. PCE Agent 117 may have ability to partition one single N concurrent path computation requests into M sessions; or to correlate M sessions and interact with PCE 116 to avoid double booking during an iterative path computation mode. PCE Agent 117 may also derive a point-to-multi-point traffic matrix for point-to-multi-point applications, when PCE 116 has ability to compute point-to-multi-point paths.

[0025] In another embodiment, PCE Agent 117 may perform reconfiguration of Optical LSPs (O-LSPs). PCE Agent 117 may provide an automatic reconfiguration detection mechanism. The reconfiguration detection mechanism may detect under-utilized O-LSPs and well-performing O-LSPs using a periodic polling mechanism. The reconfiguration detection mechanism may also run a reconfiguration algorithm to determine candidates for reconfigured/re-optimized O-LSPs.

[0026] Furthermore, the reconfiguration detection mechanism may be used to initiate a re-optimization path computation request to PCE 116 for under-utilized O-LSPs. In addition, the reconfiguration detection mechanism may provide constraints to PCE 116 in a path re-optimization computation request. The constraints may include new objective functions, list of paths to be re-optimized, or list of paths that may not be removed/changed. The list of paths that may not be removed/changed may be placed as a global constraint in a path computation request.

[0027] Communications between PCE 115 and PCE 116, and between PCE 116 and PCE Agent 117, are through PCE Communication Protocol (PCECP). When receiving a signaling request to end at an Egress Node 138, an Ingress Node 132 communicates with PCE 115 through PCECP, asking for a path computation. PCE 115 may communicate with PCE 116 for lower-layer path information, and returns a computed path to Ingress Node 132. Ingress Node 132 then proceeds a signaling procedure using the computed path, and reaches Egress Node 138 by passing through Area Border Router (ABR) 134 and 136. ABR 134 and 136 may also be an Autonomous System Border Router (ASBR).

[0028] ABR 134 may request PCE 116 to provide a light path via PCECP, when a computed path arriving at ABR 134 from Ingress Node 132 is infeasible, or when information of a computed path is not sufficient. PCE Agent 117 may provide static optical layer path provisioning with cooperation of PCE 116, establishing optical LSPs by communicating with optical gateway nodes 122 and 124.

[0029] The distributed PCE-based architecture in the present invention fits well in inter-domain multi-layer applications (i.e., a higher-layer service provider is different from a lower-layer service provider, e.g., carrier's carrier applications). The distributed PCE-based architecture also facilitates vertical integration of two separate service administrative domains in a provider's network.

[0030] Reference is now made to Fig.2, a diagram 200 illustrating an embodiment of a Static Optical Layer Path Provisioning (SOLPP) mode in an Optical Transport Network (OTN) layer.

[0031] The static path provisioning is basically a lower-layer specific function that establishes optical LSPs on a pre-establishment basis, before a higher-layer client LSP may request LSPs in the lower layer. In the distributed system architecture of the present invention, a PCE (Lo) 216 and a PCE Agent 217 play key roles in preestablishing optical TE LSPs using a traffic demand matrix.

[0032] In step 252, traffic forecast data 242 arrives at PCE Agent 217 from a network planning system. PCE Agent 217 may be viewed as part of the network planning system. PCE Agent 217 sorts out traffic forecast data 242 to produce a point-to-point demand matrix that maps to the optical network topology and available network resources.

[0033] Output of the sort-out may be a set of candidate LSPs, including ingress nodes, egress nodes, bandwidth, protection types, diversity requirements (e.g., link, node, or shared risk link group-SRLG) of protection paths for 1+1 protection, etc. This output may be formulated in terms of a Global Concurrent Path Computation Request (GCPCReq) message to PCE 216.

[0034] A Global Concurrent Path Computation is referred to as a large-scale concurrent path computation, where a large number of TE paths are to be computed concurrently, in order to efficiently utilize network resources. A computation method involved with a large-scale concurrent path computation is referred to as global concurrent optimization.

[0035] In Step 254, PCE 216 receives a GCPCReq from PCE Agent 217. PCE 216 solves a mathematical optimization problem to find an optimal solution that meets global objective functions and global constraints, while satisfying each individual path constraint. A key constraint may be computing multiple paths concurrently, as opposed to computing path sequentially, which conventionally may result in sub-optimal use of resources. PCE 216 in this sense is a specialized high-capacity computing engine.

[0036] An optimal computation result is reported back to PCE Agent 217 by PCE 216 in the form of a Path Computation Reply (PCRep) message, in which each computed LSP is indicated. There are cases where the computation result is infeasible. Reasons for infeasibility may be memory issues, computational infeasibility, or other problems. PCE 216 may send the following information back to the PCE Agent 217 to indicate result of a global concurrent path computation request.

[0037] An indicator field indicates the outcome of the request. When the PCE could not find a feasible solution with the initial request, the reason for infeasibility should be indicated. Certain indicators should be supported, including: feasible solution found, mathematically infeasible, and memory overflow.

[0038] In step 256, PCE Agent 217 receives a path computation result from PCE 216. If the computation result from PCE 216 is infeasible, then PCE Agent 217 may stop the PCReq process at this point.

[0039] When PCE Agent 217 receives a path computation result indicating that the computation is infeasible (e.g., mathematically or memory overflow), PCE Agent 217 may try a different option under network policies. A policy option may be iterative path computation. Iterative path computation is a way to partition the one session of concurrent path computation requests (e.g., M total path computation requests) into N sessions (M>N), so that each session may require less computational burden than one single big session. This option may be exercised when a large scale optimization computation fails to find a feasible solution.

[0040] If PCE Agent 217 receives a successful result from PCE 216, then in step 258, for each feasible LSP computed by PCE 216, PCE Agent 217may initiate a Generalized Multiprotocol Label Switching (GMPLS) Resource Reservation Protocol (RSVP) Path request to an optical gateway node 222 associated with the LSP.

[0041] In step 260, GMPLS signaling procedure may be proceeded, through downstream optical core nodes as prescribed as an Explicit Router Object (ERO) in a PATH message. When an optical gateway node 224 receives the PATH message, it sends back a Reservation (RESV) message to upstream.

[0042] In step 262, the RESV message arrives at PCE Agent 217 from optical gateway node 222 associated with the LSP. When an RESV message arrives from optical gateway node 222, an LSP establishment completes.

[0043] In step 264, PCE Agent 217 updates a TED 212 with the newly established LSP.

[0044] The same procedure may be repeated until all LSPs are established.

[0045] Fig.3 is a diagram 300 illustrating an embodiment of a Dynamic Multi-Layer Path Provisioning (DMLPP) mode. DMLPP is referred to as a multi-layer path provisioning process, which is triggered by a higher-layer dynamically to find an end-to-end LSP. DMLPP involves cooperative path computations between a PCE (Hi) 315 and a PCE (Lo) 316.

[0046] In step 351, Ingress Node 332 receives a signaling request to set up a PATH that ends at an Egress Node 338. Ingress Node 332 requests PCE 315 for an end-to-end path computation in step 352. In step 353, if PCE 315 determines that it does not have sufficient routing information for a lower-layer, a PATH Request message is triggered to PCE 316 for a lower-layer path computation. In step 354, PCE 316may compute lower-layer path segments using a TED (Lo) 314, and report the computation result back to PCE 315. Upon receipt of a lower-layer path computed by PCE 316, PCE 315 formulates a multi-layer path, using a TED (Hi) 312, and sends the multi-layer path result back to Ingress Node 332 in step 355. Ingress Node 332, upon receipt of the end-to-end path result from PCE 315, proceeds signaling procedures using the computed path, passing through ABR 334, OTN 322, OTN 324, and ABR 336, reaching Egress Node 338, going back to Ingress Node 332, and establishing a multi-layer path.

[0047] Fig.4 is a diagram 400, illustrating an embodiment of process flows when a Crankback takes place in a DMLPP mode.

[0048] A Crankback arises when a PCE (Hi) 415 successfully finds an end-to-end path with steps illustrated in Fig.4, and an Ingress Node 432 proceeds with the path suggested by PCE (Hi) 415 and PCE (Lo) 416. As a PATH message proceeds through an optical transport network (aka, lower layer network), one of the nodes in an O-LSP may send a crankback indicator in a PATH ERROR message back to an upper layer ABR (i.e., the optical LSP is no longer available for service or the committed bandwidth is not available for service). Upon receipt of the crankback indication, the first ABR node in the network, i.e., ABR 434, may have two choices to proceed. One choice is that the PATH ERROR may be sent to an upstream, and the path request may terminate. This is referred to as a normal crankback process. The second choice is that a PCReq may be sent to PCE 416, for a real-time path computation in the OTN, while holding off the crankback report to an upstream. The second choice is referred to as a Crankback Holdoff mode.

[0049] Under the Holdoff option, ABR 434 is allowed to request a path computation on the fly, before ABR 434 proceeds with a normal crankback procedure. Normal crankback procedure is held off by ABR 434. When ABR 434 obtains a new light path from PCE 416, ABR 434 may try to set up a new path; otherwise, ABR 434may proceed with the normal crankback process.

[0050] In step 451, an OTN 422 detects that an LSP request may not be accepted due to lack of resources, and sends a PATH ERROR message to ABR 434. ABR 434 (under policy) may request a new PCReq message to PCE 416 in step 452. PCE 416 computes a new light path using a TED (Lo) 414, and replies back to ABR 434 with a computed path in step 453. If under a normal signaling flow, ABR 434 may take a normal crankback procedure by sending a PATH ERROR message to an upstream.

[0051] Upon receiving a path report from PCE 416 in step 453, if a new light path is found, ABR 434 may proceed a PATH signaling to downstream with the new light path in the OTN. Otherwise, i.e., a new path is not found, a PATH ERROR message would proceed back to an upstream.

[0052] Crankback holdoff mode is beneficial in saving path setup time if successful. Path computation policies should allow ABRs to authorize a request to a lower-layer path computation on the fly (i.e., dynamically).

[0053] The previous description of the disclosed embodiments is provided to enable those skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art.

Claims

1. A distributed Path Computation Element based, PCE-based, system in a multi-layer network, **characterized by** comprising:

at least one higher-layer PCE(115, 315, 415), adapted to compute packet layer Label Switched Paths, LSPs;

at least one lower-layer PCE(116,216, 316, 416), adapted to compute optical layer LSPs responsive to a request of the at least one higher-layer PCE (115, 315, 415);

at least one higher-layer Traffic Engineering Database(112, 312, 412), TED, adapted to provide relevant Traffic Engineering link information to the at least one higher-layer PCE(115, 315, 415);

at least one lower-layer TED(114, 212, 314, 414), adapted to provide relevant Traffic Engineering link information to the at least one lower-layer PCE(116,216, 316, 416); and

at least one PCE Agent(117, 217), adapted to interact with the at least one lower-layer PCE (116, 216, 316, 416) for optical layer LSP provisioning;

wherein the at least one higher-layer PCE(115, 315, 415) and the at least one lower-layer PCE(116,216, 316, 416) are adapted to function cooperatively for multi-layer path computations.

2. The system of claim 1, wherein the at least one lower-layer PCE(116,216) provides pre-established optical LSP information.

3. The system of claim 2, wherein the pre-established optical LSP information is requested by the at least one higher-layer PCE(115).

4. The system of claim 1, wherein the at least one lower-layer PCE(116, 316, 416) provides dynamically a new light path computation.

5. The system of claim 4, wherein the new light path computation is requested by an Area Border Router, ABR(134), in the multi-layer network.

6. The system of claim 4, wherein the new light path computation is requested by an Autonomous System Border Router, ASBR(134), in the multi-layer network.

7. The system of claim 1, wherein the at least one PCE Agent(117, 217) provides path provisioning of a lower-layer LSP.

8. The system of claim 7, wherein the at least one PCE Agent(117, 217) initiates an LSP setup in a lower-layer.

9. The system of claim 7, wherein the path provisioning is driven by network planning.

10. The system of claim 7, wherein, the at least one PCE Agent(117, 217) initiates a global concurrent path computation to the at least one lower-layer PCE(116,216) using a traffic demand matrix.

11. The system of claim 1, wherein the at least one PCE Agent(117, 217) communicates with the at least one lower-layer PCE(116,216) for computation of a lower-layer LSP.

12. The system of claim 11, wherein the at least one PCE Agent(117, 217) provides a point-to-point traffic matrix.

13. The system of claim 11, wherein the at least one PCE Agent(117, 217) provides a global concurrent path computation request to the at least one lower-layer PCE(116,216).

14. The system of claim 11, wherein the at least one PCE Agent(117, 217) communicates with a PCE policy server to obtain decision parameters for a global concurrent path computation.

15. The system of claim 11, wherein the at least one PCE Agent(117, 217) provides an iterative path computation if an initial global concurrent path computation fails.

16. The system of claim 15, wherein the at least one PCE Agent(117, 217) partitions a plurality of concurrent path computation requests into multiple sessions; and correlates the multiple sessions.

17. The system of claim 11, wherein the at least one PCE Agent(117, 217) provides a point-to-multi-point traffic matrix for point-to-multi-point applications.

18. The system of claim 1, wherein the at least one PCE Agent(117, 217) provides reconfiguration of lower-layer LSPs.

19. The system of claim 18, wherein the at least one PCE Agent(117, 217) provides an automatic reconfiguration detection mechanism.

20. The system of claim 19, wherein the automatic reconfiguration detection mechanism detects under-utilized optical LSPs using a periodic polling mechanism.

21. The system of claim 19, wherein the automatic reconfiguration detection mechanism detects well-performing optical LSPs using a periodic polling mechanism.

22. The system of claim 19, wherein a reconfiguration algorithm is run to determine candidates for reconfigured or re-optimized optical LSPs using the automatic reconfiguration detection mechanism.

23. The system of claim 19, wherein the automatic reconfiguration detection mechanism initiates a re-optimization path computation request to the at least one lower-layer PCE(116,216) for under-utilized optical LSPs.

24. The system of claim 19, wherein the automatic reconfiguration detection mechanism provides constraints to the at least one lower-layer PCE(116,216) in a path re-optimization computation request.

25. The system of claim 24, wherein the constraints comprise new objective functions, a list of paths to be re-optimized, and a list of paths that are not to be removed or changed.

26. The system of claim 1, wherein a static optical layer path provisioning mode is provided.

27. The system of claim 1, wherein a dynamic multi-layer path provisioning mode is provided.

28. The system of claim 1, wherein a crankback hold-off

method is provided and the crankback hold-off method comprises:

an ABR(434) requesting a new path computation to the at least one lower-layer PCE(116, 416), upon detecting a crankback condition;
the at least one lower-layer PCE(116, 416) providing a new light path; and
the ABR(434) proceeding path signaling using the new light path.

Patentansprüche

1. Verteiltes auf einem Pfadberechnungselement basiertes System, PCE-basiertes System, in einem Mehrschichtnetz, **dadurch gekennzeichnet, dass** es Folgendes umfasst:

wenigstens ein PCE (115, 315, 415) einer höheren Schicht, das dafür ausgelegt ist, etikettvermittelte Pfade, LSP, einer Paketschicht zu berechnen;
wenigstens ein PCE (116, 216, 316, 416) einer niedrigeren Schicht, das dafür ausgelegt ist, als Reaktion auf eine Anforderung von dem wenigstens einen PCE (115, 315, 415) einer höheren Schicht LSP einer optischen Schicht zu berechnen;
wenigstens eine verkehrstechnische Datenbank (112, 312, 412), TED, einer höheren Schicht, die dafür ausgelegt ist, relevante verkehrstechnische Verbindungsinformationen für das wenigstens eine PCE (115, 315, 415) einer höheren Schicht bereitzustellen;
wenigstens eine TED (114, 212, 314, 414) einer niedrigeren Schicht, die dafür ausgelegt ist, relevante verkehrstechnische Verbindungsinformationen für das wenigstens eine PCE (116, 216, 316, 416) einer niedrigeren Schicht bereitzustellen; und
wenigstens einen PCE-Agenten (117, 217), der dafür ausgelegt ist, mit dem wenigstens einen PCE (116, 216, 316, 416) einer niedrigeren Schicht zu interagieren, um einen LSP einer optischen Schicht bereitzustellen;
wobei das wenigstens eine PCE (115, 315, 415) einer höheren Schicht und das wenigstens eine PCE (116, 216, 316, 416) einer niedrigeren Schicht dafür ausgelegt sind, zusammenwirkend für Mehrschichtpfad-Berechnungen zu funktionieren.

2. System nach Anspruch 1, wobei das wenigstens eine PCE (116, 216) einer niedrigeren Schicht im Voraus erstellte Informationen eines optischen LSP bereitstellt.

3. System nach Anspruch 2, wobei die im Voraus erstellten Informationen eines optischen LSP von dem wenigstens einen PCE (115) einer höheren Schicht angefordert werden.

4. System nach Anspruch 1, wobei das wenigstens eine PCE (116, 316, 416) einer niedrigeren Schicht eine neue Lichtpfadberechnung dynamisch bereitstellt.

5. System nach Anspruch 4, wobei die neue Lichtpfadberechnung von einem Bereichsgrenzen-Router, ABR, (134) in dem Mehrschichtnetz angefordert wird.

6. System nach Anspruch 4, wobei die neue Lichtpfadberechnung von einem autonomen Systemgrenzen-Router, ASBR, (134) in dem Mehrschichtnetz angefordert wird.

7. System nach Anspruch 1, wobei der wenigstens eine PCE-Agent (117, 217) eine Pfadbereitstellung eines LSP einer niedrigeren Schicht bereitstellt.

8. System nach Anspruch 7, wobei der wenigstens eine PCE-Agent (117, 217) eine LSP-Einrichtung in einer niedrigeren Schicht initiiert.

9. System nach Anspruch 7, wobei die Pfadbereitstellung durch Netzplanung angesteuert wird.

10. System nach Anspruch 7, wobei der wenigstens eine PCE-Agent (117, 217) eine globale konkurrente Pfadberechnung zu dem wenigstens einen PCE (116, 216) einer niedrigeren Schicht unter Verwendung einer Verkehrsanforderungsmatrix initiiert.

11. System nach Anspruch 1, wobei der wenigstens eine PCE-Agent (117, 217) mit dem wenigstens einen PCE (116, 216) einer niedrigeren Schicht für eine Berechnung eines LSP einer niedrigeren Schicht kommuniziert.

12. System nach Anspruch 11, wobei der wenigstens eine PCE-Agent (117, 217) eine Punkt-zu-Punkt-Verkehrsmatrix bereitstellt.

13. System nach Anspruch 11, wobei der wenigstens eine PCE-Agent (117, 217) eine globale konkurrente Pfadberechnungsanforderung für das wenigstens eine PCE (116, 216) einer niedrigeren Schicht bereitstellt.

14. System nach Anspruch 11, wobei der wenigstens eine PCE-Agent (117, 217) mit einem PCE-Strategie-Server kommuniziert, um Entscheidungsparameter für eine globale konkurrente Pfadberechnung zu erhalten.

15. System nach Anspruch 11, wobei der wenigstens eine PCE-Agent (117, 217) eine iterative Pfadberechnung bereitstellt, falls eine anfängliche globale konkurrente Pfadberechnung scheitert.

16. System nach Anspruch 15, wobei der wenigstens eine PCE-Agent (117, 217) mehrere konkurrente Pfadberechnungsanforderungen auf mehrere Sitzungen aufteilt; und die mehreren Sitzungen korreliert.

17. System nach Anspruch 11, wobei der wenigstens eine PCE-Agent (117, 217) eine Punkt-zu-Mehrpunkt-Verkehrsmatrix für Punkt-zu-Mehrpunkt-Anwendungen bereitstellt.

18. System nach Anspruch 1, wobei der wenigstens eine PCE-Agent (117, 217) eine Neukonfiguration von LSP einer unteren Schicht bereitstellt.

19. System nach Anspruch 18, wobei der wenigstens eine PCE-Agent (117, 217) einen Mechanismus zum Detektieren einer automatischen Neukonfiguration bereitstellt.

20. System nach Anspruch 19, wobei der Mechanismus zum Detektieren einer automatischen Neukonfiguration unter Verwendung eines Mechanismus zum periodischen Abfragen nicht ausgelastete optische LSP detektiert.

21. System nach Anspruch 19, wobei der Mechanismus zum Detektieren einer automatischen Neukonfiguration unter Verwendung eines Mechanismus zum periodischen Abfragen gut ausgelastete optische LSP detektiert.

22. System nach Anspruch 19, wobei ein Neukonfigurationsalgorithmus ausgeführt wird, um Kandidaten für neu konfigurierte oder neu optimierte optische LSP unter Verwendung des Mechanismus zum Detektieren einer automatischen Neukonfiguration zu bestimmen.

23. System nach Anspruch 19, wobei der Mechanismus zum Detektieren einer automatischen Neukonfiguration eine Neuoptimierungspfad-Berechnungsanforderung zu dem wenigstens einen PCE (116, 216) einer niedrigeren Schicht für nicht ausgelastete optische LSP initiiert.

24. System nach Anspruch 19, wobei der Mechanismus zum Detektieren einer automatischen Neukonfiguration Einschränkungen für das wenigstens eine PCE (116, 216) einer niedrigeren Schicht in einer Pfadneuoptimierungs-Berechnungsanforderung bereitstellt.

25. System nach Anspruch 24, wobei die Einschränkungen neue Zielfunktionen, eine Liste von neu zu optimierenden Pfaden und eine Liste von Pfaden, die nicht entfernt oder geändert werden sollen, umfassen.

26. System nach Anspruch 1, wobei ein Modus zum Bereitstellen eines statischen Pfades einer optischen Schicht bereitgestellt wird.

27. System nach Anspruch 1, wobei ein Modus zum Bereitstellen eines dynamischen Mehrschichtpfads bereitgestellt wird.

28. System nach Anspruch 1, wobei ein "Crankback"-Sperrverfahren bereitgestellt wird und das "Crankback"-Sperrverfahren Folgendes umfasst:

ein ABR (434) fordert eine Neupfadberechnung bei dem wenigstens einen PCE (116, 416) einer niedrigeren Schicht bei Detektion einer "Crankback"-Bedingung an;
das wenigstens eine PCE (116, 416) einer niedrigeren Schicht stellt einen neuen Lichtweg bereit; und
der ABR (434) führt eine Pfadsignalisierung unter Verwendung des neuen Lichtwegs aus.

Revendications

1. Système à base d’Elément de Calcul de Chemin, PCE, distribué dans un réseau multicouches, **caractérisé en ce qu’**il comprend :

au moins un PCE de couche supérieure (115, 315, 415), adapté pour calculer des Chemins Commutés par Etiquettes, LSP, de couches de paquets ;
au moins un PCE de couche inférieure (116, 216, 316, 416), adapté pour calculer des LSP de couches optiques en réponse à une requête de l’au moins un PCE de couche supérieure (115, 315, 415) ;
au moins une Base de Données d’Ingénierie de Trafic, TED, de couche supérieure (112, 312, 412), adaptée pour fournir des informations de liaison d’Ingénierie de Trafic pertinentes à l’au moins un PCE de couche supérieure (115, 315, 415) ;
au moins une TED de couche inférieure (114, 212, 314, 414), adaptée pour fournir des informations de liaison d’Ingénierie de Trafic pertinentes à l’au moins un PCE de couche inférieure (116, 216, 316, 416) ; et
au moins un Agent PCE (117, 217), adapté pour interagir avec l’au moins un PCE de couche inférieure (116, 216, 316, 416) pour l’approvision-

nement des LSP de couches optiques ;
dans lequel l'au moins un PCE de couche supérieure (115, 315, 415) et l'au moins un PCE de couche inférieure (116, 216, 316, 416) sont adaptés pour fonctionner en coopération pour les calculs de chemins multicouches.

2. Système selon la revendication 1, dans lequel l'au moins un PCE de couche inférieure (116, 216) fournit des informations de LSP optiques préétablies.

3. Système selon la revendication 2, dans lequel les informations de LSP optiques préétablies sont requises par l'au moins un PCE de couche supérieure (115).

4. Système selon la revendication 1, dans lequel l'au moins un PCE de couche inférieure (116, 316, 416) assure dynamiquement un nouveau calcul de chemin optique.

5. Système selon la revendication 4, dans lequel le nouveau calcul de chemin optique est requis par un Routeur Limitrophe de Zone, ABR (134), dans le réseau multicouches.

6. Système selon la revendication 4, dans lequel le nouveau calcul de chemin optique est requis par un Routeur Limitrophe de Système Autonome, ASBR (134), dans le réseau multicouches.

7. Système selon la revendication 1, dans lequel l'au moins un Agent PCE (117, 217) assure l'approvisionnement de chemin d'un LSP de couche inférieure.

8. Système selon la revendication 7, dans lequel l'au moins un Agent PCE (117, 217) lance un établissement de LSP dans une couche inférieure.

9. Système selon la revendication 7, dans lequel l'approvisionnement de chemin est piloté par une planification de réseau.

10. Système selon la revendication 7, dans lequel l'au moins un Agent PCE (117, 217) lance un calcul de chemin simultané global vers l'au moins un PCE de couche inférieure (116, 216) en utilisant une matrice de demande de trafic.

11. Système selon la revendication 1, dans lequel l'au moins un Agent PCE (117, 217) communique avec l'au moins un PCE de couche inférieure (116, 216) pour calculer un LSP de couche inférieure.

12. Système selon la revendication 11, dans lequel l'au moins un Agent PCE (117, 217) fournit une matrice de trafic point à point.

13. Système selon la revendication 11, dans lequel l'au moins un Agent PCE (117, 217) fournit une requête de calcul de chemin simultané global vers l'au moins un PCE de couche inférieure (116, 216).

14. Système selon la revendication 11, dans lequel l'au moins un Agent PCE (117, 217) communique avec un serveur de règles de PCE pour obtenir des paramètres de décision pour un calcul de chemin simultané global.

15. Système selon la revendication 11, dans lequel l'au moins un Agent PCE (117, 217) assure un calcul de chemin itératif si un calcul de chemin simultané global échoue.

16. Système selon la revendication 15, dans lequel l'au moins un Agent PCE (117, 217) divise une pluralité de requêtes de calcul de chemin simultané en de multiples sessions ; et met en corrélation les multiples sessions.

17. Système selon la revendication 11, dans lequel l'au moins un Agent PCE (117, 217) fournit une matrice de trafic point-multipoint pour des applications point-multipoint.

18. Système selon la revendication 1, dans lequel l'au moins un Agent PCE (117, 217) assure une reconfiguration des LSP de couche inférieure.

19. Système selon la revendication 18, dans lequel l'au moins un Agent PCE (117, 217) fournit un mécanisme de détection de reconfiguration automatique.

20. Système selon la revendication 19, dans lequel le mécanisme de détection de reconfiguration automatique détecte des LSP optiques sous-utilisés en utilisant un mécanisme d'interrogation périodique.

21. Système selon la revendication 19, dans lequel le mécanisme de détection de reconfiguration automatique détecte des LSP optiques fonctionnant correctement en utilisant un mécanisme d'interrogation périodique.

22. Système selon la revendication 19, dans lequel un algorithme de reconfiguration est exécuté pour déterminer des LSP optiques candidats à reconfigurer ou réoptimiser en utilisant le mécanisme de détection de reconfiguration automatique.

23. Système selon la revendication 19, dans lequel le mécanisme de détection de reconfiguration automatique lance une requête de calcul de chemin de réoptimisation vers l'au moins un PCE de couche inférieure (116, 216) pour des LSP optiques sous-utilisés.

24. Système selon la revendication 19, dans lequel le mécanisme de détection de reconfiguration automatique fournit des contraintes à l'au moins un PCE de couche inférieure (116, 216) dans une requête de calcul de réoptimisation de chemin.

25. Système selon la revendication 24, dans lequel les contraintes comprennent des nouvelles fonctions d'objectif, une liste de chemins à réoptimiser, et une liste de chemins qui ne doivent pas être supprimés ou changés.

26. Système selon la revendication 1, dans lequel un mode d'approvisionnement de chemin de couche optique statique est fourni.

27. Système selon la revendication 1, dans lequel un mode d'approvisionnement de chemin multicouches dynamique est fourni.

28. Système selon la revendication 1, dans lequel un procédé d'attente de reroutage automatique est fourni et le procédé d'attente de reroutage automatique comprend :

la requête par un ABR (434) auprès de l'au moins un PCE de couche inférieure (116, 416) d'un nouveau calcul de chemin à la détection d'une condition de reroutage automatique ;
la fourniture par l'au moins un PCE de couche inférieure (116, 416) d'un nouveau chemin optique ; et
le lancement par l'ABR (434) de la signalisation de chemin en utilisant le nouveau chemin optique.

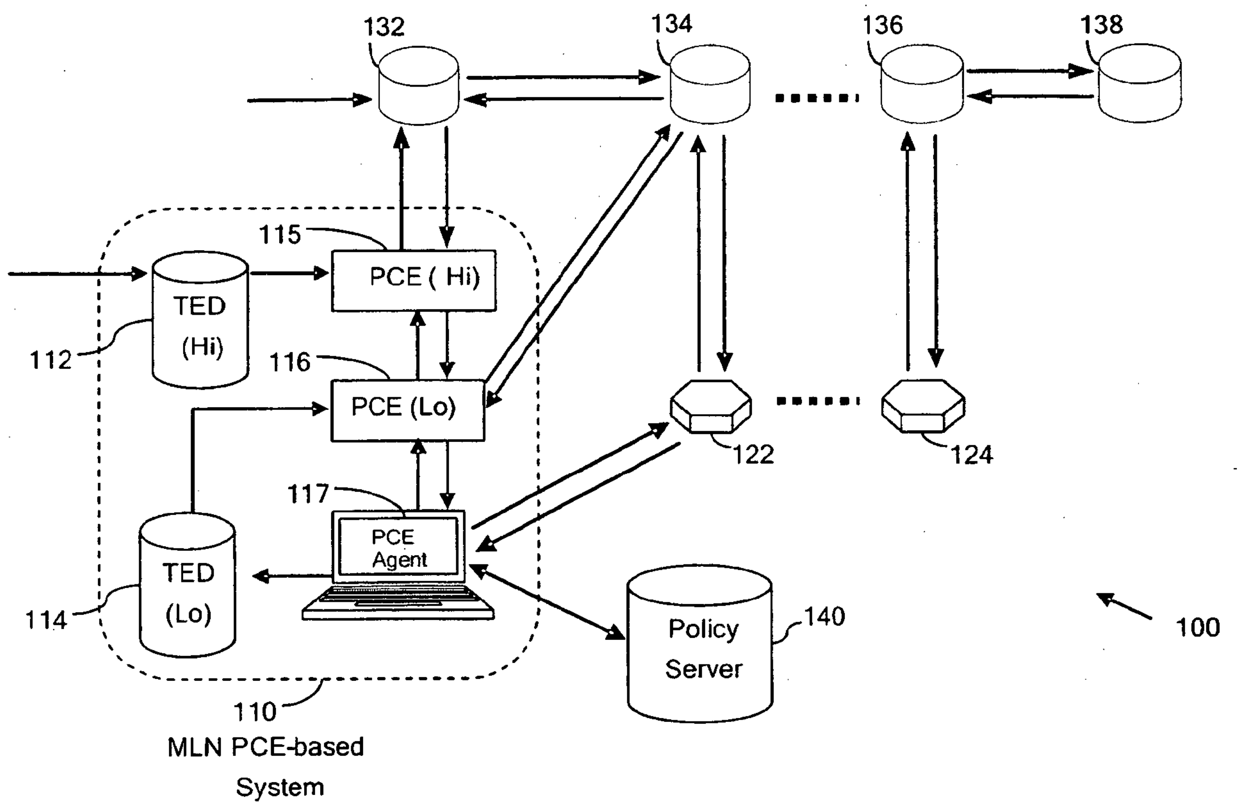
132
134
136
138
115
PCE (Hi)
TED
(Hi)
112
116
PCE (Lo)
122
124
117
PCE
Agent
TED
(Lo)
114
Policy
Server
140
100
110
MLN PCE-based
System

Fig.1

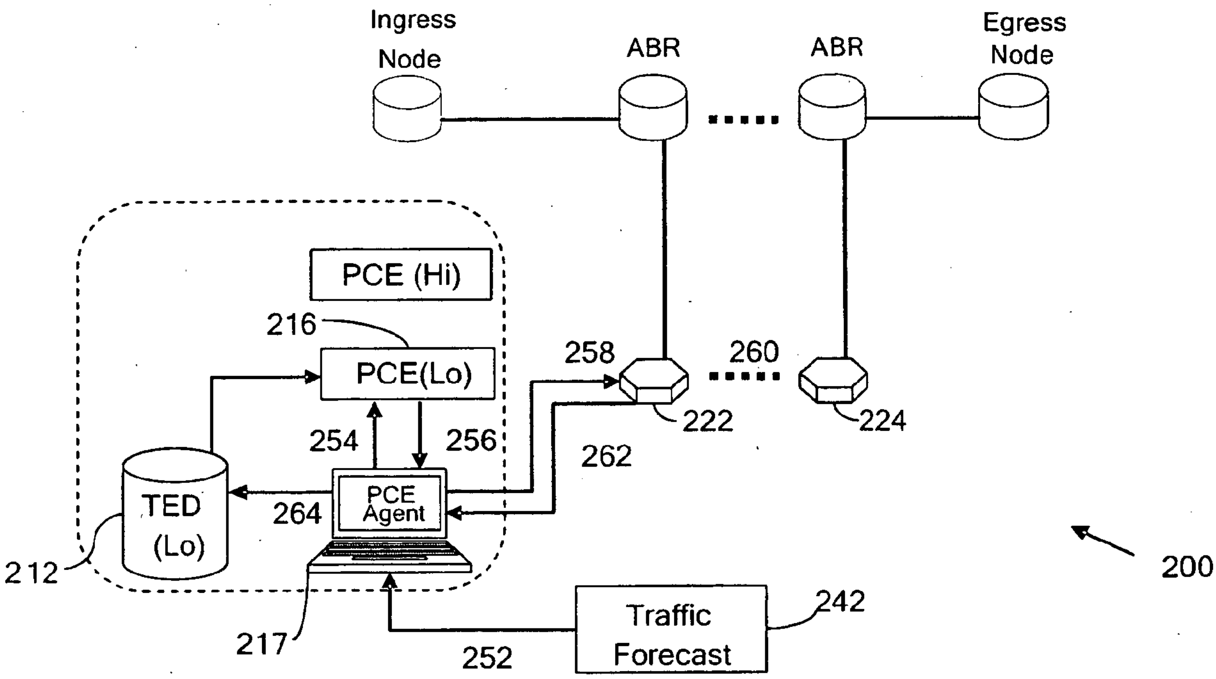
Ingress Node
ABR
ABR
Egress Node
PCE (Hi)
216
PCE(Lo)
258
260
222
224
254
256
262
TED (Lo)
264
PCE Agent
212
200
242
Traffic Forecast
217
252

Fig.2

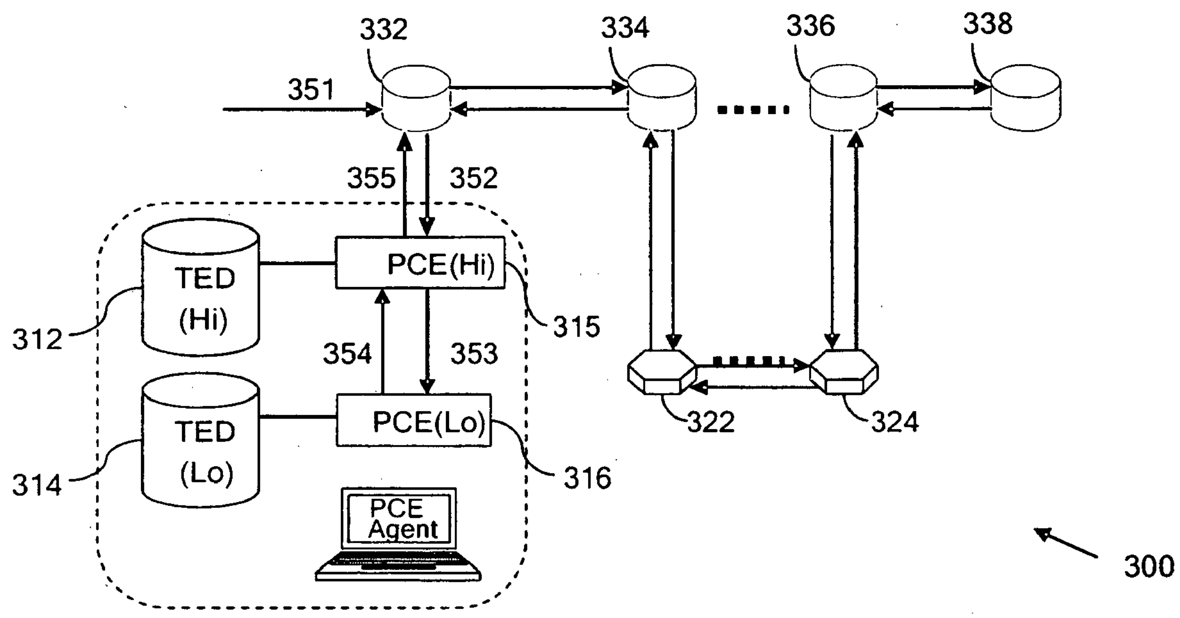
332
334
336
338
351
355
352
TED
(Hi)
PCE(Hi)
312
315
354
353
TED
(Lo)
PCE(Lo)
314
316
PCE
Agent
322
324
300

Fig.3

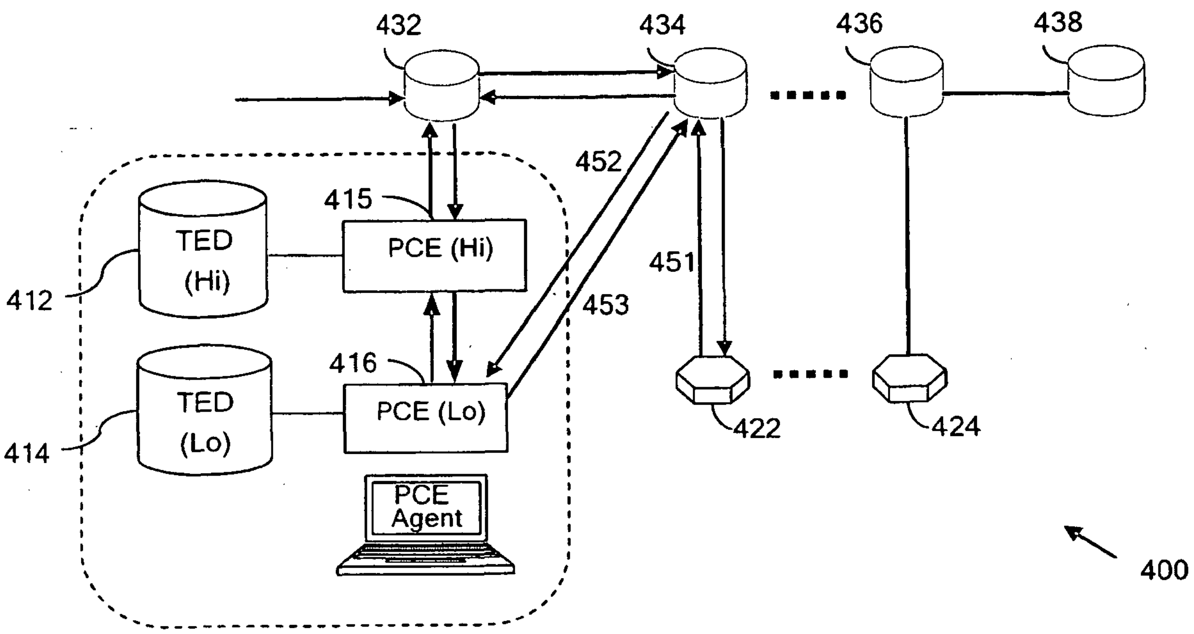
432
434
436
438
452
415
PCE (Hi)
TED
(Hi)
412
451
453
416
PCE (Lo)
TED
(Lo)
414
422
424
PCE
Agent
400

Fig.4

REFERENCES CITED IN THE DESCRIPTION

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