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Comparison of Monte-Carlo and Stochastic dynamic programming techniques to optimize WAN redundancy of corporate network

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Abstract: Organizations now a day have grown from nice-to-have to must-have feature of redundancy in their WAN (Wide Area Network) infrastructure to succeed in their business. A lengthy research have taken place in terms of eliminating critical application downtime, WAN link redundancy optimization, fail over mechanisms, bandwidth aggregation traffic shaping, QOS etc., but focus is not given to either device failures or reliability optimization, design optimization based on cost and stochastic distribution of component reliabilities of this kind was never discussed. Here an attempt is made to design WAN redundancy using Monte Carlo simulation and SDP approaches and carefully applied to a practical network, thoroughly studied and results are compared.

Keywords: Monte Carlo Simulation, Optimal design of complex systems, Stochastic Dynamic Programming Technique, WAN redundancy design.

INTRODUCTION

Organizations now a day are looking for features like Reliable, availability and serviceability (RAS) from nice to have situation to must-have situation. In order to offer the quoted services the organizations must give emphasize on the things like Redundancy design. The network designers involving in WAN design are responsible for the optimal design within the budget limits of the organization. To setup a reliable network access across all the branch offices of corporate companies, the designer has to focus on the things like available space, devices cost and the overall budget of the wide area network. To the best of my knowledge there very less number of decision support systems to assist the network designer. In this paper it is planned to plan develop and evaluate the optimal redundancy design for WAN using a single user decision support system. At the end of the paper the two decisions generated are compared. Normally the no two devices manufactured, even in a batch also doesn't have the same reliability. Further the network devices reliabilities are assumed to be stochastic in nature. Evaluation of WAN reliability is of very much complex because vast numbers of network devices are used for various objectives in the network. Evaluating reliability of such complex system [1],[3] is truly time consuming and results into errors. After carefully analyzing the suitability of various optimization techniques it is decided to develop Stochastic Programming Technique for the devices reliabilities dynamically varies. A single user decision support system is developed to assist the network designers. The system supports two techniques known as Monte Carlo simulation and Stochastic Dynamic Programming [2] (SDP) technique. Both of the decision support systems are implemented and tested for various redundancy levels in the language JDK1.6.

PRACTICAL NETWORK CONSIDERED FOR COMPARISON CONSIDERED FOR COMPARISON

The redundancy evaluation of computer communication networks [6],[7] is much complex especially when the devices reliability values are random or stochastic in nature. To evaluate the WAN redundancy design for practical networks used by the corporate organization needs to be studied narrowly. In case of increasing more availability usually alternative paths is erected so that when a primary path fails an alternative path is selected for data transfers. Similarly routing devices in corporate head offices are connected in dual. But it is not guaranteed to offer services all the time due to multiple device failures or natural calamity occurrences. In the corporate WAN, infrastructure like edge routers, security appliances like firewalls and regional routers etc., is been used. It is decided to consider the design parameters cost, number of devices and complex configuration (usually in wide area networks). Further to simplify the design calculations the size of the network is planned to include the core devices is only considered. Devices like edge router, security appliances like firewall, proxy server and database servers are excluded in the

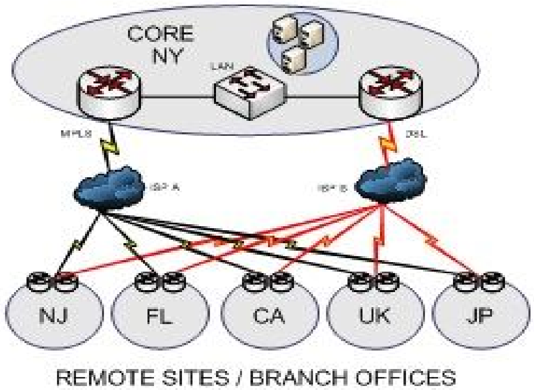

Fig 1 Typical corporate WAN with redundancy

network considered for comparing the two methods. The wide area network configuration used for the development of single user decision support system is shown in fig. 1. The branch offices located in New Jersey, Florida, Canada, United Kingdom and Japan are connected to New York core with redundant links using MPLS and DSL internet connections. The primary links connected are shown in black where as the redundant link [5] are shown in red color. Similarly the routers in the New York core are in also configured with redundancy. However in the event of failure of one router the traffic is not routed automatically. The branch offices need to choose the alternative path available.

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Hence the suggested redundancy configuration for each of the WAN device needs to be made redundant to meet catastrophic device failures. The network device names for the typical WAN configuration can be read from fig. 2. The corporate Server(s) usually runs web server, database or mail servers either in one or multiple hosts. Here only one server is considered for redundancy optimization denoted by IS, The links are extended to the branch offices through routers are denoted by R-1, R-2 and Switch banks S-1, S-2,S-3 and S-4. Each of the switches in the switch bank is assumed of low cost and planned to place at least 8 per bank. When connected in a redundancy of 8 and over the redundancy of switch bank will almost become 1. Hence these devices are not included in the design of WAN redundancy.

DATAFLOW IN THE WAN

The various interconnections are shown in the fig. 2. These interconnections are usually redundant in order to increase availability irrespective of the failure incidents. Switches at the branch offices connect to the client machines of other branch office client machines through internet server. The traffic from branch offices is routed through the corresponding switches, routers then through the Internet Server. The intra-traffic is ignored in the redundancy design. The Multi-branch corporate office performs their daily transaction like database updates, business reports will be exchanged among their branch offices. The central office connections are established through their virtual connections using internet. The established link should be reliable till the intended task is successfully finished. Sometimes CRM people also involve in the information updates is carried through their mobile devices using broadband or wireless connections. These mobile users and their connections are not shown in the fig. 2.

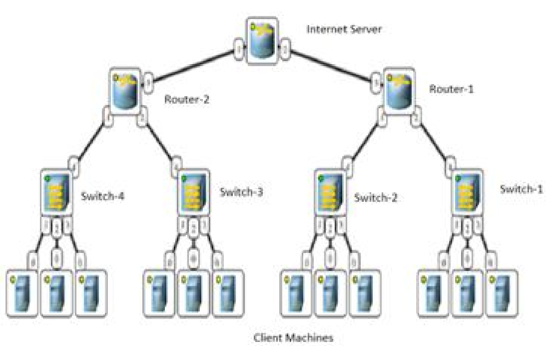

Fig 2 Simplified Multi Branch organization's WAN for day-to-day operations.

Normally the four branch offices are connected using devices like Wireless LAN controller, Branch Routers, Client Access Switches, Internet Edge routers. The transactions performed by the employees are also protected under Email Security Appliances, Firewall, Web security appliances, Distribution Switches and Wireless Access points are typically used. In order to simplify the design and testing such a complex network most of the components are not shown in figure. The actual network for which the optimization techniques are to be applied is simplified because of complex expressions involved in the evaluations.

ASSUMPTIONS FOR THE COMPLEX NETWORK (WAN) UNDER CONSIDERATION

The internet server is been accessed by the employees through switches. Each switch in the network forms a subnet connects up to 24 client machines where as only three client machines are shown in fig. 2. The number of client machines can be easily extended as and when there is a need. The switches are in turn connected to routers and then to the internet server (or corporate server). The Multi Branch Organization (MBO) usually maintains redundant devices for all the critical devices in active redundancy mode. However whenever a particular network device fails the switching circuit delinks the failed device and brings the spared device into action by a triggering circuit. All this happens in a flash. The basic problem we need to focus on multiple device failures or hazardous incident can't be handled successfully. Hence we must focus on WAN redundancy design in order to offer uninterrupted services among the branch offices. The basic problem here is that incase the redundant components also fails then a service break occurs between the branch offices to corporate offices. in the services offered to the branch offices. The Organization thus needs to allocate sufficient budget to meet the failover circumstances.

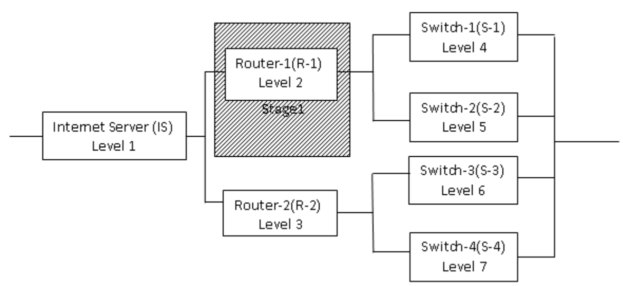

Fig 3 Equivalent diagram for complex WAN under consideration

For the simplified corporate network it is assumed to install ten parallel switches with reliability of 0.7 each at all the branch offices because of their low cost @ Rs. 3000/- per switch. These switches are assumed to be at level 4 in the system. Further when the reliability of the switches is evaluated it comes to one. Thus the problem is further simplified to evaluate the WAN reliability comprising of internet server at level 1, router-1(R-1) at level 2 also known as subsystem1, router-2(R-2) at level 3 also known as subsystem2. The overall budget spared for the WAN should not exceed 10Lacs. Apart from this due to space constraints it is also decided not to consider more than six redundant devices at each level of the network.

THE MONTE-CARLO METHOD TO ESTIMATE WAN RELIABILITY.

To evaluate the Networks max. reliability using the monte-Carlo[9] simulation a customized algorithm for a 3 Stage Network is shown in fig. 4.

Procedure MONTE_CARLO(BudgetAllocated)

; Rs – Reliability of System(WAN)

; Tc – Total budget alloted to the WAN

Rs ← 0.0

Tc ← 10L

; Comb – possible combinations for various devices in the networ.

Comb ← 0

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```
sc ← 0
maxIter ← 5000
M  ← get_iterations();
Rs ← 0.0       // reliability of the system   i=1 server, i=2
router, i=3 router i=4 switch1, i=5 switch6, i=6 switch7, i=7
switch8
N ← get(read_no_of_redundant_devices)
for i=1 to N
get_device[i]       // i = device id
get_device[i+1]       // i+1 = device cost
get_device[i+2]       // i+2 = device reliability
get_device[i+3]       // i+3 = device probability
get_device[i+4]       // i+4 = device random number
end for
procede ← 1
do{
   for each device combination id =1 to N
sc ← sc + get_device_cost[k+1]
If(sc<=BudgetAllocated) then
         Comb ← Comb + 1
         For each iter=1 to M
            For each get_device[i]
         rndnum = RndSeed()
compare get_device[i+4] with the random number generated
            get_device[i+2]
         relia[i++] =Evaluate device reliability
         End for
         Evaluate system reliability using relia and store;
      End for
   End if
End for
Procede ← 0
}
While(Procede)
For each combination 1 to N
MRComb ← SearchMaxRel();
Return SystemDetails(MRComb)
End for
Return
```

Fig 4: Algorithm to find maximum reliability using redundant devices using Monte Carlo simulation

The simulation is executed for 5000 iterations. In actual to get the results close to the theoretical values the simulation has to be executed infinite number of times. As it consumes lot of system space and computational resources the no. of iterations are limited to just 5000. After the execution max. reliability of the WAN is obtained for six devices at each of the stage in the network.

PRACTICAL SETUP AND RESULTS OF SDP TECHNIQUE

The reliability is evaluated with the Monte Carlo simulation technique under the assumed constraints as components costs and no of components. After running the simulation for each of the possible combinations for 5000 times the best network reliable combination is found to be 6 Servers, 6 routers in branch1 and 6 routers in branch2 with max. reliability of 0.979695. The cost of system for the best reliable components setup is 9,30,000/- The developed software package is very flexible to install and use with normal system configuration. For the WAN environment within the budget and number of redundant devices constraint the optimal redundancy is evaluated. With the same constraints the stochastic redundancy problem is formulated to compare this simulation result to arrive at the solution. For the WAN using Monte-Carlo simulation technique the optimized number of redundant components at each level of network the optimal no. of redundant components at each level is evaluated!

A. The SDP method to evaluate Computer Network reliability:

In stochastic dynamic programming technique for the complex computer network under consideration using the similar constraints. The SDP technique here applied is multistage decision problem considering a single variable at atime. The N subproblems are decomposed in such a manner that the optimum result is obtained for the N variables under consideration.

The use of recurrence relationship required in section 3.4 in actual computations is discussed in this chapter. Dynamic programming starts by sub optimizing the last component, numbered 1 which involves the determination of

$$\mathbf{f_1^*(s_2) = opt_{x_1}[R_1(x_i, s_2)]} \quad \ldots\ldots\ (1)$$

The optimal value of the decision variable x_1, which is denoted by x_1* is that which makes the return (or objective) function R_1 presume its best valve denoted by f_1*.

The values xi* and f1* depend on the input condition that the component 1 gets from the upstream i.e., on s_2. Since the particular value 's_2' will assume after the upstream level components are optimized is not known at this time, until last stage sub optimization problem is solved for a range of feasible values of 'S_2' . The results are entered into a graph or a table that contains a complete abstract of the results of sub optimization and stage 1. In few cases, it may be possible to define f_1* as a function of 'S_2'. If the calculations are to be executed on a computer, the sub optimization results have to be stored in the computer in the form of a table.

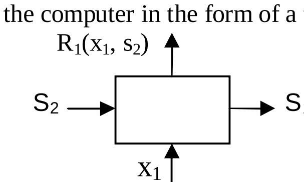

Fig 5. Sub optimization of component 1 for different resources and constraints and the input state variable s2.

TABLE 4.1 SUB- OPTIMIZATION OF COMPONENT 1 FOR DIFFERENT SETTINGS OF THE INPUT STATE VARIABLE S2.

S_2	X_1	f_1	S_1
--	--	--	--
--	--	--	--
--	--	--	--
--	--	--	--
--	--	--	--

Results obtained from the sub optimization of stage 1 are entered in a typical table shown in Table 4.1. Next we progress up the serial system to include the final two components. For this two stage optimization, we have to find out

$$f_2^*(s_3) = \mathrm{opt}_{x_3,x_1}[R_2(x_2,s_3) + R_i(x_1,s_2)] \ \ldots\ldots\ldots\ (2)$$

As all the information about component 1 has been encoded earlier in the table corresponding to f1*, the same

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information can be altered for R1 in equation (2) for getting the following simplified statement.

$$f_2^*(s_3) = \text{opt}_{x_2}[R_2(x_2, s_3) + f_i^*(x_1, s_2)] \ldots\ldots \quad (3)$$

The random distribution function for the Internet Server and the two routers under consideration are as follows. The mean reliabilities of internet server, routers are evaluated using the failure data collected from the branch offices and main office is as given here.

Component	Reliability	Probability	Expected mean Reliability	Design variables of redundancy
IS	0.7	0.35	0.8	n_1
	0.8	0.3		
	0.9	0.35		
R-1	0.4	0.3	0.5	n_2
	0.5	0.4		
	0.6	0.3		
R-2	0.6	0.4	0.7	n_3
	0.7	0.2		
	0.8	0.4		

35% of the internet servers are having a reliability value of 0.7, another 30% of the IS's reliability is 0.8 where as the remaining servers reliability is 0.9. For the routers used in subsystem1 using the failure data available the probability and the reliability of the devices is evaluated to 30% of the devices have 0.4 reliability, 40% the routers having with 0.5 and 30% of the switches with 0.6 reliability. Similarly for the router 2 used in subsystem 2 the reliability and probabilites are like this, 40% of the devices have 0.6 reliability, 20% the routers having with 0.7 and 40% of the switches with 0.8 reliability. From this data the mean reliabilities are evaluated as

$r_{IS} = 0.7 * 0.35 + 0.8 * 0.3 + 0.9 * 0.35 = 0.8$

$r_2 = 0.4 * 0.3 + 0.5 * 0.4 + 0.6 * 0.3 \quad = 0.5$

$r_3 = 0.6 * 0.4 + 0.7 * 0.2 + 0.8 * 0.4 \quad = 0.7$

The mean reliabilities of internet server is thus evaluated to 0.95 * 0.4 + 0.96 * 0.5 + 0.97 * 1 = 0.957

The mean reliabilities of router1 and router2 is evaluated to 0.9 * 0.3 + 0.92 * 0.5 + 0.95 * 0.2 = 0.92.

In any computer network a reliable connection depends on the end to end connectivity, thus each of the network device is assumed to be a segment. Each of such segments is assumed as a sub problem and decisions are taken in each stage to evaluate the optimum reliability of the system.

In multistage decision problems each of the single stage is represented by a rectangular box denoting the active stage. Each of the stage is characterized by certain input parameters like reliability of the component and decision parameters like cost and space to produce an output parameter as an outcome obtained as a result of making the decision.

Procedure SDP (BudgetAllocated)
$R_s \leftarrow 0.0$
$T_c \leftarrow 10L$
comb ← 0
maxIter ← 6
max_ss1_components ← 1
max_ss2_components ← 1
max_ss3_components ← 1
no_of_sw_components ← 40
cost_of_sw ← 3000
total_sw_cost ← no_of_sw_components * cost_of_sw
get_details(no_of_sub_systems)
for stage=1 to no_of_sub_systems
    get_ind_stage_details(sub_system_id, cost_of_device, reliability,probability)
end for
evaluate mean_relia_of_sub_systems
for SS_1=1 to BudgetAllocated – (cost of one component in the remaining subsystems + tsw)
evaluate the feasible values for SS_1
evaluate individual return function for SS_1
store cost and individual retrun function of SS1
end for
for SS_2=1 to BudgetAllocated – (cost of one component in the remaining subsystems + tsw)
    evaluate the feasible vlues for SS_2
    evaluate individual return function for SS_2
    evaluate combined return function for SS_2
    evaluate optimum reliability of SS_2
end for
for ss=1 to BudgetAllocated – (cost of one component in the remaining subsystems +tsw)
    evaluate the feasible vlues for ss
    evaluate individual return function for ss
    evaluate combined return function for ss
    optR[i++] ← evaluate optimum reliability system
end for
For noi=1 to i
mrComb ← SearchMaxRel(optR);
Return SystemDetails(mrComb)
End for
Return

Figure 6: Algorithm to find optimal redundancy using SDP technique for the WAN System.

The two algorithms are implemented in JDK1.6 as said in the introduction. The hypothetical case input data given for the Monte-Carlo simulation and SDP Technique are given the same values. The sample input screen for the SDP technique is given in figure 6.

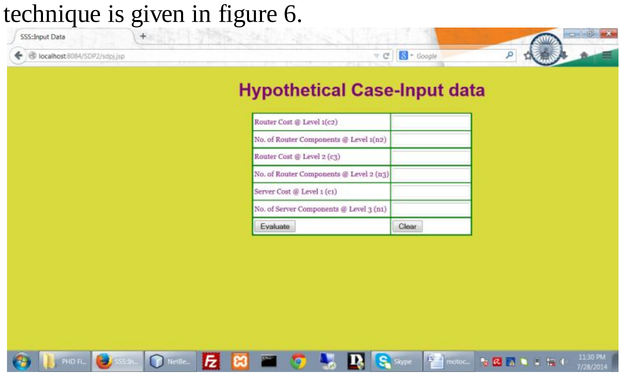

Fig 6. Output screen to input Hypothetical data for SDP Technique.

After obtaining the stage one output i.e., optimal reliability for stage 1 comprising level 1 component R-1. The second stage return function is evaluated. For that first second stage reliability values are estimated, after that the return values from stage 1 is retrieved. After obtaining the two values the unreliability's of each of the two stages are multiplied to get the second stage eliability. Finally the Max. value for each of the feasible value for stage 2 cost and number of components in second stage are evaluated. Finally the return function is evaluated by finding the max. value of each of the feasible value for the given network devices in stage 1 and stage 2.

This process is repeated to evaluate the optimal reliability of the WAN combining the stages. Then the Optimum reliability of the WAN is extracted from which looking back to stage 2 and stage 1 optimum values the complete WAN reliability is evaluated. And it is found to be 6componets of redundance at each stage of WAN.

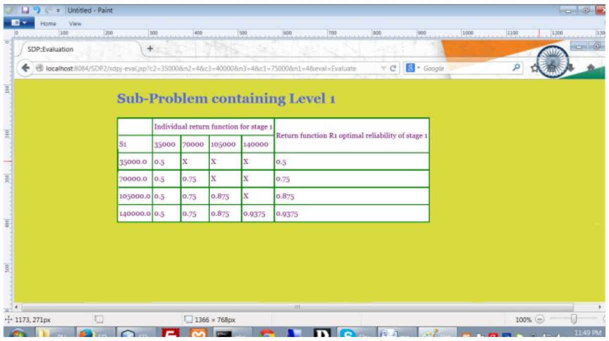

Fig 7. Output screen showing subsystem1 return function.

The output obtained for the hypothetical input data for subsystem1 optimization is given in figure 7. However the remaining stages output is not shown due to space constraint. The obtained output reveals after the three levels optimization is that the number of redundant components in each of the stage is 6.

RESULTS AND ANALYSIS

WAN – A complex network comprising of server, routers and switches should be reliable to make the network of computers to continuously function down the line. Hence optimal redundancy design of WAN within the budget limits the network design as well as maximum operational reliability is of the concern in this work. Stochastic dynamic programming is successfully applied to design standby redundancy for various components of WAN with the objective of max reliability of WAN. A java package is developed to arrive at optimal solutions using SDP approach for wide area networks and the same is applied for a WAN under consideration and evidenced that optimal redundancy at level 1, level 2 and level 3 is found to be n1=6, n2=6, n3=6 and fixed no. of switches at level 4 with optimal redundancy of 0.99992461.

CONCLUSION

The complex redundant network design of WAN under consideration is veteran using the two optimization techniques.The results of the two techniques implies that both the methods gives the optimal solution within the given constraints. In future the can be subjected to other constraints for strict evaluation of the WAN design. For the given cost constraint the maximum reliability is obtained for the combination of six internet servers, six routers in the subsystem SS_1 and six routers in the second subsystem2 SS_2.

REFERENCES

1. C.Nadamuni Reddy, K.Sathish Babu,(1999),“Optimal Redundancy of a three unit series system- Dynamic Programming Approach”, presented at a National Seminar on Technology Management Beyond 2000, on Nov. 23rd & 24th.
2. C.Nadamuni Reddy, (1998),“Optimal Unit Commitment of a Power System-DP Approach”, Paper presented at International Conference on Operations research and Industry, held at Agra, India during Dec. 19th-21th
3. Dr C.Nadamuni Reddy, (1998), “Reliability Optimization oa a Series Syatem- A Search Technique, Paper presented at Intenational Conference on Operations research and Industry (ORSI Convention) held at Agra, India during Dec. 19th-21th
4. C.Nadamuni Reddy, & Dr.C.Umashankar,(1998),“Optimization of System Reliability-Dynaic Programming Aproach, International Conference on Stochastic Processes and Numerical Modeling, held at Utkal University, Bhubaneswar, Jan 6th-8th
5. J.K. Cavers, “Cutset manipulations for communication network reliability estimation”, IEEE Transactions on Communications, Vol. 23, 1975, pp. 569–575.
6. M. Ball, R.M. Van Slyke, “Backtracking algorithms for network reliability analysis”, Annals of Discrete Mathematics, Vol. 1, 1977, pp. 49 – 64.
7. K.K. Aggarwal, S. Rai, “Reliability evaluation in computer-communication networks”, IEEE Transactions on Reliability, Vol. 5, 1981, pp. 30 – 32.
8. Y.C. Chopra, B.S. Sohi, R.K. Tiwari, K.K Aggarwal, “Network topology for Maximizing the terminal reliability in a computer communication network”, Microelectronics & Reliability, Vol. 3, 1984, pp. 911–924.
9. G.S. Fishman, “A Monte Carlo sampling plan for estimating network reliability”, Operations Research, Vol. 34, 1986, pp. 581–594.
10. Abd-El-Barr M., Zakir A., Sait, SM., Almulhem A.,“Reliability and fault tolerance based topological optimization of computer networks,” IEEE Pacific Rim Conference on Communications, Computers, and Signal Processing, Vols. 1 and 2, Conference Proceedings;Victoria-Canada, pp: 736-739, 2003.
11. Chuiwei Lu, Zhengbing Hu, “A fault-tolerant routing algorithm of p2p network based on hierarchical structure,” Proceedings of 2nd International Conference e-Business and Information System Security (EBISS), pp. 1-4, Wuhan- China, 2010.
12. Shooman Mortin L, “Reliability of computer systems and networks: fault tolerance, analysis, and design,” John Wiley & Sons, Inc., 2002.
13. Peterson Larry, Davie Bruce, “Computer Network a System Approach,” Morgan Kaufmann, 4th Edition, 2007.
14. Technical Data Sheet for Cisco Catalyst 2960 Series Switches with LAN Base Software, page 14. Published by Cisco Systems, Inc., 2009.