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# Information Technology Proposal for the Town of Spencer

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**CLARK**  
UNIVERSITY



**Masters Science in Information Technology Capstone  
Spring 2016**

**Prepared for the Town of Spencer by**

**Vijay Basava  
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## Executive Summary

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The Town of Spencer came to us looking for a plan to build and maintain their own personal fiber network for connection between departments and to improve data security for important information. After assessing the existing landscape and determining the various paths forward, we created network diagrams and plans for the movement forward of this project.

After assessing a variety of plans, we found that a full single-mode fiber network would be the best system for the implementation in Spencer. While it was the highest cost, it also scored the highest in our assessment.

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## I. Project Statement

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**Client:** Town of Spencer

**Goal:** To centralize town information services, improve information security, and reduce costs associated with the existing VPN system through the construction of a fiber optic network.

**Process:** This proposal is laid out in four phases with each phase having 4 options presented. These phases can be completed independently over-time or in a singular fashion. Each phase covers a segmentation of the network and a general change to the existing infrastructure. These segmentations encompass the creation of a central network backbone connecting two primary sites, integration of secondary sites into the new fiber network, establishment of redundant network pathways, and finally centralization of domain services and control.

Each of the four-by-four phases will be presented with logical and physical network maps to aid with the planning process. These will be further accompanied with an analysis of needed equipment to accomplish the given task and a breakdown of the individual costs associated. Selected equipment options represent enterprise products appropriate for the scale of the system and the user requirements.

## II. Requirements

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The new network needed to meet certain standards to justify the investment in new infrastructure. The existing network relied on a system of hardware-driven virtual private networks (VPNs) that accessed central services over the public internet channels. We took this as our performance baseline in establishing the requirements for the new system.

We decided that it must meet four core requirements:

- Improve Security
- Improve Reliability
- Scalable
- Positive Cost Benefit

In order to achieve this goal, we needed to establish some set guidelines and assumptions. First, we approached this design as a replacement of the network topology. Second, we established the usage of the town hall as the central data hub for information services within the network. Third, we would select equipment that would be a similar grade to the existing hardware. This allowed us to have a given price range for the planning of equipment acquisition above and beyond what was already in place. As much of the hardware was configured for the VPN, much of the work would be primarily in the links and not a full swap of the existing switches and firewalls. Existing routing tables would need to be updated to properly encompass the new network elements.

We established the following plan of action:

- **Assess the capacity and needs of the network.**
- **Formulate a variety of plans that would meet the stated goals.**
- **Rank the plans according to a set scale.**
- **Construct general equipment lists based upon the selected plan.**
- **Estimate construction and implementation costs.**
- **Engineer and test network design in a virtual environment.**
- **Assess possible risks and solutions.**

Following this plan allowed us to create several models and test them out as we went through them. This helped to ensure the most appropriate and thoroughly tested model going forward. We further broke down the team components into smaller units to allow each of us to focus on their individual strengths.

### III. Technical Analysis

Town of Spencer  
Municipal Fiber Map - Preliminary  
February 2016  
Clark University MSIT



**Legend**

- Locations
- Backbone
- Secondary
- Tertiary

Name	Order
Fire Department	6
Police Department	5
EMS	4
Highway Department	8
Water	9
Sewer	7
Library	1
Town Hall	2
Senior Center	3
Junction	10

Our first analysis needed to be a look at the existing setup of the Town of Spencer. We began by plotting out the various locations of the sites and creating optimal routes between them. This let us examine the pathways and distance of fiber runs that we would be required to plan for. Plotting this points into a GIS map gave us an approximate distance that we would be able to utilize for further calculations.

Number	Location	Junction	Approximate Distance to Junction meters (feet)	Connection(s)
2	Town Hall	N\A	N\A	N\A
1	Library	1	200m (660')	Fiber\Wireless
3	Senior Center	1	615m (2030')	Fiber\Wireless
9	Water	10	1800m (5940')	Single Mode Fiber
7	Sewer	5	1000m (3300')	Single Mode Fiber
8	Highway	5	670m (2211')	Fiber
5	Fire	10	780m (2574')	N\A
6	Police	N\A	N\A	N\A
4	EMS	5	70m (231')	Fiber
10	Junction Point	2	760m (2508')	Fiber

Once we had approximate distances, we were able to determine the type of fiber that would be required for connecting these sites. As some of the links were greater than 550 meters, we knew that the network would either need to be a hybrid of

singlemode fiber and multimode fiber, or one of pure single mode fiber to maintain the necessary bandwidth. We calculated out that there would be roughly 20,000 feet of fiber optic capable that would need to be installed in just the primary and secondary connections.

## IV. Network Topology and Design

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Using our technical requirements, we decided that the best method to pursue would be the creation of four plans that would have distinct phases. These plans would encompass a range of options and we would be able to assess them upon five key criteria: cost, speed, reliability, scalability, and security.

We defined these as such:

**Cost** – The total cost of ownership of the plan over a three year stretch

**Speed**- The maximal bandwidth attainable in the system

**Reliability**- How stable the network would be and how much it would mitigate risks of downtime

**Scalability** – How ‘future-proof’ can we create the network for the expansion of services or encompassment of new ones

**Security** – To what extent can we ensure the data integrity and security of information being transmitted across this network

Our four plans would be based upon different systems. The first would be fully singlemode fiber, the second plan would be a mix of singlemode fiber and high speed point-to-point wireless connections. Our third plan would be a full network of multimode running at 100BaseFX and the fourth plan would be a blend of multimode fiber and slower point-to-point wireless. We assessed these plans based on a high/medium/low scale.

Plan	Cost	Speed	Reliability	Scalability	Security
A - SM	H	H	H	H	H
B - SM\Wifi	M	H	M	M	M
C - MM	M	L	H	L	H
D - MM\Wifi	L	L	M	L	L

## VI. Financial Assessment

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In order to assess the cost of each project, we tried to find some accurate pricing in terms of fiber installation and the overall cost. What we did find is that it varies quite a bit between area and scope of the project. Ultimately, we used a cost database provided by the department of transportation to figure out a rough range for construction costs. We set a price range of 1.50 to 2.50 per linear foot, with singlemode fiber being on the more expensive end of that range and multimode being cheaper. This price was based on the placement of 8-12 strand fiber optic lines.

In terms of wireless equipment, we decided upon a single manufacturer for consistency and familiarity. Point to point wireless systems function as a virtual Ethernet link and can be relatively easy to setup. The two models that we assessed had a wide range in price due to the specifications, but ultimately we arrived at two prices. For the faster 1.2+ Gbps connection, we'd utilize the Ubiquiti AirFiber 5 at a cost of \$2000 for the the full pair and mounting equipment. The slower speed of the multimode network could function on a much cheaper piece of hardware. The Ubiquiti Nanobeam 5AC can maintain speeds of 450 Mbps but at one tenth of the cost, a mere \$200 for a pair with mounting equipment. Data tables for the calculations can be found in the appendix. Total capital costs were calculated for each of the four plans and assessed.

Plan	Description	Distance	Cost
A	All buildings connected with Singlemode fiber, 8 strand per pull	~20427'	40854.00
B	Main buildings connected with Singlemode fiber, 8 strand per pull; PtP – Senior Center, Library	~17725'	\$35450.00 + 4000.00 for Wireless connections
C	Multimode network running at 100BaseFX, 8 strand per pull	~20427'	\$30640.00
D	Main buildings connected with Multimode fiber at 100BaseFX, 8 strand per pull; PtP – Senior Center, Library	~17725'	\$26587.00 + \$400.00 for Wireless connections

## VII. Network Assessment

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When planning out our network design, we had a few standard principles to uphold. We wanted to construct the network in such a way that it would maintain data granularity and security as we brought the additional sites on line. Ultimately, we ended up with three networks to maintain: the local area network of the individual sites, the metropolitan area network between the sites, and the wide area network access to the internet gateway.

To maximize efficiency within the system, we focused on the construction of a narrow vlan for handling routing traffic while still allowing for easy access to other portions of the network through proper subnetting. This would minimize the amount of broadcasts occurring over the fiber network and helping to maximize the available throughput on the network. Full design specifications are found in the appendix.

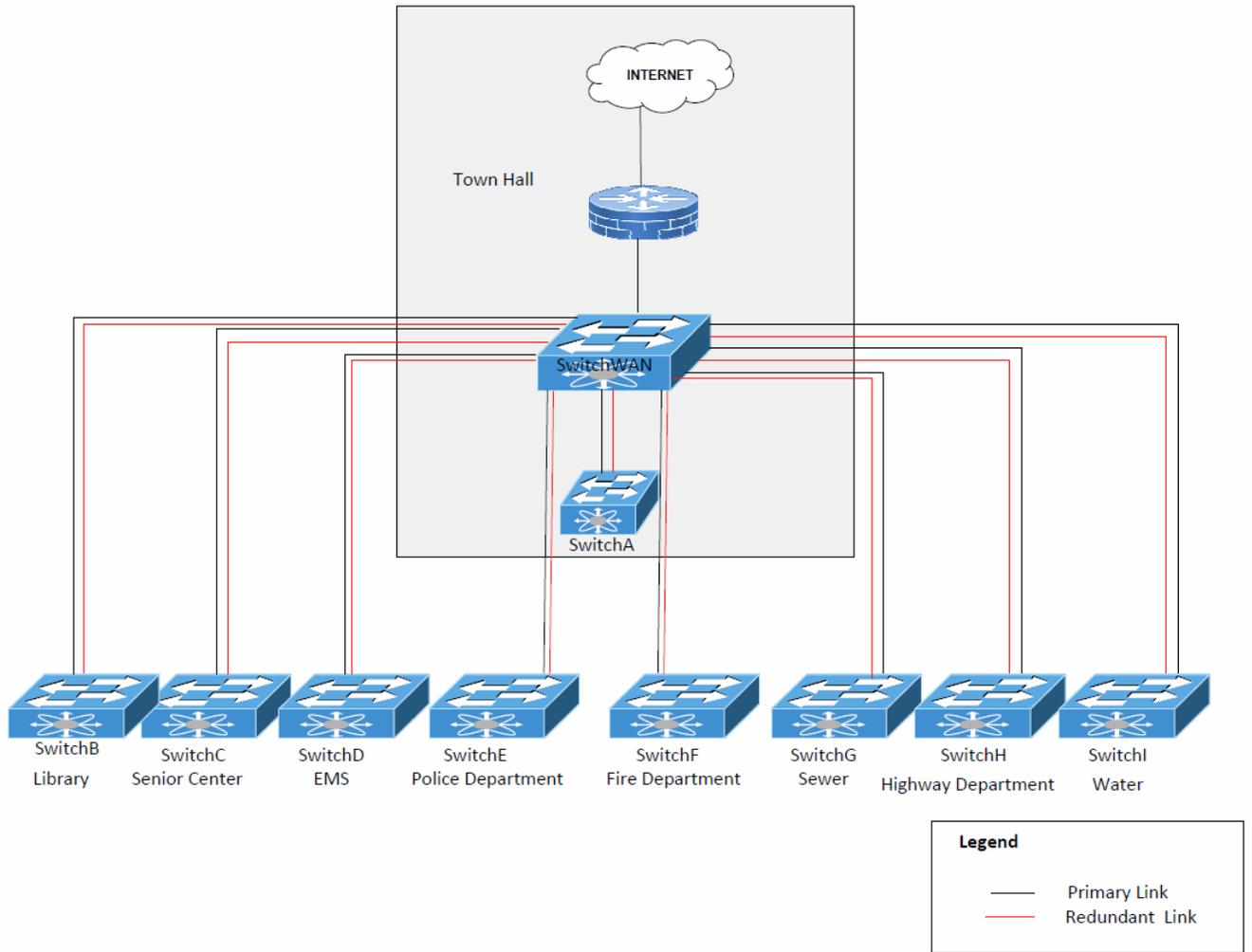
## VIII. Risk Assessment

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To determine risk for this project, we wanted to focus on the differences between a VPN network and a private fiber network. We wanted to take a look at the chance of network outages, security leaks, slow bandwidth, and the ability to audit for both systems. Ultimately, it came down to the various factors of why people have moved towards or away from physical private networks. We utilized this in deciding if this project was feasible to move forward upon and if it actually had enough benefit.

# IX. Appendix

## Switch Diagram



## Switch Model List

WS-C2960XR-24TD-I 9 Qty

WS-C4500X-24X-IPB 1 Qty

SFP-10G-LR-S 32 Qty

SFP-10G-SR 4 Qty

## Configuration Files

SwitchWAN

hostname SwitchWAN

!

logging console emergencies

!

username admin privilege 15 password Vijay

no aaa new-model

system mtu routing 1500

!

spanning-tree mode pvst

spanning-tree extend system-id

!

!

interface range te1/0/1-2

no switchport

channel-group 1 mode active

!

interface range te1/0/3-4

no switchport

channel-group 2 mode active

no sh

!

interface range te1/0/5-6

no switchport

channel-group 3 mode active

```
no sh
!  
interface range te1/0/7-8  
no switchport  
channel-group 4 mode active  
no sh  
!  
interface range te1/0/9-10  
no switchport  
channel-group 5 mode active  
no sh  
!  
interface range te1/0/11-12  
no switchport  
channel-group 6 mode active  
no sh  
!  
interface range te1/0/13-14  
no switchport  
channel-group 7 mode active  
no sh  
!  
interface range te1/0/15-16  
no switchport  
channel-group 8 mode active  
no sh  
!  
interface range te1/0/17-18  
no switchport  
channel-group 9 mode active  
no sh  
!
```

```
interface te 1/0/19
description InternetFirewall
no switchport
ip add 172.168.0.38 255.255.255.252
no sh
!
interface Port-channel1
description SwitchA
no switchport
ip address 172.16.0.2 255.255.255.252
no sh
!
interface Port-channel2
description SwitchB
no switchport
ip address 172.16.0.6 255.255.255.252
no sh
!
interface Port-channel3
description SwitchC
no switchport
ip address 172.16.0.10 255.255.255.252
no sh
!
interface Port-channel4
description SwitchD
no switchport
ip address 172.16.0.14 255.255.255.252
no sh
!
interface Port-channel5
description SwitchE
```

```
no switchport
ip address 172.16.0.18 255.255.255.252
no sh
!
interface Port-channel6
description SwitchF
no switchport
ip address 172.16.0.22 255.255.255.252
no sh
!
interface Port-channel7
description SwitchG
no switchport
ip address 172.16.0.26 255.255.255.252
no sh
!
interface Port-channel8
description SwitchH
no switchport
ip address 172.16.0.30 255.255.255.252
no sh
!
interface Port-channel9
description SwitchI
no switchport
ip address 172.16.0.34 255.255.255.252
no sh
!
!
interface Vlan1
no ip address
shutdown
```

```
!  
ip routing  
ip route 0.0.0.0 0.0.0.0 172.16.0.37  
ip route 172.16.1.0 255.255.255.0 172.16.0.1  
ip route 172.16.2.0 255.255.255.0 172.16.0.5  
ip route 172.16.3.0 255.255.255.0 172.16.0.9  
ip route 172.16.4.0 255.255.255.0 172.16.0.13  
ip route 172.16.5.0 255.255.255.0 172.16.0.17  
ip route 172.16.6.0 255.255.255.0 172.16.0.21  
ip route 172.16.7.0 255.255.255.0 172.16.0.25  
ip route 172.16.8.0 255.255.255.0 172.16.0.29  
ip route 172.16.9.0 255.255.255.0 172.16.0.33  
!  
line con 0  
  exec-timeout 0 0  
  login local  
line vty 0 4  
  
  login local  
  transport input telnet  
line vty 5 15  
  login local  
  transport input telnet  
!  
!  
End  
  
SwitchA  
hostname SwitchA  
!  
logging console emergencies  
!
```

```
username admin privilege 15 password Vijay
no aaa new-model
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan 10
name data
!
interface range te1/1/1-2
no switchport
channel-group 1 mode active
!
interface range Gig 1/0/1-24
switchport
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
description SwitchWAN
no switchport
ip address 172.16.0.1 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.1.0 255.255.255.0
```

```
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.2
!
line con 0
exec-timeout 0 0
login local
line vty 0 4

login local
transport input telnet
line vty 5 15
login local
transport input telnet
!
!
end

SwitchB
hostname SwitchB
!
logging console emergencies
!
username admin privilege 15 password Vijay
no aaa new-model
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan 10
```

```
name data
!
interface range te1/1/1-2
no switchport
channel-group 1 mode active
!
interface range Gig 1/0/1-24
switchport
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
descriptiom SwitchWAN
no switchport
ip address 172.16.0.5 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.2.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.6
!
line con 0
exec-timeout 0 0
```

```
login local
```

```
line vty 0 4
```

```
login local
```

```
transport input telnet
```

```
line vty 5 15
```

```
login local
```

```
transport input telnet
```

```
!
```

```
!
```

```
End
```

```
SwitchC
```

```
hostname SwitchC
```

```
!
```

```
logging console emergencies
```

```
!
```

```
username admin privilege 15 password Vijay
```

```
no aaa new-model
```

```
system mtu routing 1500
```

```
!
```

```
spanning-tree mode pvst
```

```
spanning-tree extend system-id
```

```
!
```

```
vlan 10
```

```
name data
```

```
!
```

```
interface range te1/1/1-2
```

```
no switchport
```

```
channel-group 1 mode active
```

```
!
```

```
interface range Gig 1/0/1-24
```

```
switchport
```

```
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
description SwitchWAN
no switchport
ip address 172.16.0.9 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.3.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.10
!
line con 0
exec-timeout 0 0
login local
line vty 0 4

login local
transport input telnet
line vty 5 15
login local
transport input telnet
```

```
!  
!  
End  
  
SwitchD  
hostname SwitchD  
  
!  
logging console emergencies  
  
!  
username admin privilege 15 password Vijay  
no aaa new-model  
system mtu routing 1500  
  
!  
spanning-tree mode pvst  
spanning-tree extend system-id  
  
!  
vlan 10  
name data  
  
!  
interface range te1/1/1-2  
no switchport  
channel-group 1 mode active  
  
!  
interface range Gig 1/0/1-24  
switchport  
swmotch mode access  
switchport access vlan 10  
no sh  
  
!  
interface Port-channel1  
descriptiom SwitchWAN  
no switchport  
ip address 172.16.0.13 255.255.255.252
```

```
no sh
!
interface Vlan1
  no ip address
  shutdown
!
interface vlan 10
ip add 172.16.4.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.14
!
line con 0
  exec-timeout 0 0
  login local
line vty 0 4

  login local
  transport input telnet
line vty 5 15
  login local
  transport input telnet
!
!
End

SwitchE
hostname SwitchE
!
logging console emergencies
!
```

```
username admin privilege 15 password Vijay
no aaa new-model
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan 10
name data
!
interface range te1/1/1-2
no switchport
channel-group 1 mode active
!
interface range Gig 1/0/1-24
switchport
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
description SwitchWAN
no switchport
ip address 172.16.0.17 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.5.0 255.255.255.0
```

```
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.18
!
line con 0
exec-timeout 0 0
login local
line vty 0 4

login local
transport input telnet
line vty 5 15
login local
transport input telnet
!
!
End

SwitchF
hostname SwitchF
!
logging console emergencies
!
username admin privilege 15 password Vijay
no aaa new-model
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan 10
```

```
name data
!
interface range te1/1/1-2
no switchport
channel-group 1 mode active
!
interface range Gig 1/0/1-24
switchport
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
descriptiom SwitchWAN
no switchport
ip address 172.16.0.21 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.6.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.22
!
line con 0
exec-timeout 0 0
```

```
login local
```

```
line vty 0 4
```

```
login local
```

```
transport input telnet
```

```
line vty 5 15
```

```
login local
```

```
transport input telnet
```

```
!
```

```
!
```

```
End
```

```
SwitchG
```

```
hostname SwitchG
```

```
!
```

```
logging console emergencies
```

```
!
```

```
username admin privilege 15 password Vijay
```

```
no aaa new-model
```

```
system mtu routing 1500
```

```
!
```

```
spanning-tree mode pvst
```

```
spanning-tree extend system-id
```

```
!
```

```
vlan 10
```

```
name data
```

```
!
```

```
interface range te1/1/1-2
```

```
no switchport
```

```
channel-group 1 mode active
```

```
!
```

```
interface range Gig 1/0/1-24
```

```
switchport
```

```
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
description SwitchWAN
no switchport
ip address 172.16.0.25 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.7.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.26
!
line con 0
exec-timeout 0 0
login local
line vty 0 4

login local
transport input telnet
line vty 5 15
login local
transport input telnet
```

```
!  
!  
End  
  
SwitchH  
hostname SwitchH  
  
!  
logging console emergencies  
  
!  
username admin privilege 15 password Vijay  
no aaa new-model  
system mtu routing 1500  
  
!  
spanning-tree mode pvst  
spanning-tree extend system-id  
  
!  
vlan 10  
name data  
  
!  
interface range te1/1/1-2  
no switchport  
channel-group 1 mode active  
  
!  
interface range Gig 1/0/1-24  
switchport  
swmotch mode access  
switchport access vlan 10  
no sh  
  
!  
interface Port-channel1  
descriptiom SwitchWAN  
no switchport  
ip address 172.16.0.29 255.255.255.252
```

```
no sh
!
interface Vlan1
  no ip address
  shutdown
!
interface vlan 10
ip add 172.16.8.0 255.255.255.0
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.30
!
line con 0
  exec-timeout 0 0
  login local
line vty 0 4

  login local
  transport input telnet
line vty 5 15
  login local
  transport input telnet
!
!
End

Switch1
hostname Switch1
!
logging console emergencies
!
```

```
username admin privilege 15 password Vijay
no aaa new-model
system mtu routing 1500
!
spanning-tree mode pvst
spanning-tree extend system-id
!
vlan 10
name data
!
interface range te1/1/1-2
no switchport
channel-group 1 mode active
!
interface range Gig 1/0/1-24
switchport
swmotch mode access
switchport access vlan 10
no sh
!
interface Port-channel1
description SwitchWAN
no switchport
ip address 172.16.0.33 255.255.255.252
no sh
!
interface Vlan1
no ip address
shutdown
!
interface vlan 10
ip add 172.16.9.0 255.255.255.0
```

```
no sh
!
!
ip routing
ip route 0.0.0.0 0.0.0.0 172.16.0.34
!
line con 0
exec-timeout 0 0
login local
line vty 0 4

login local
transport input telnet
line vty 5 15
login local
transport input telnet
!
!
end
```