IBM Spectrum Scale Network

Network flows

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Outline

- Overview
- Types of Network traffic in IBM Spectrum Scale environment
- Components
- Component traffic flow
- Other resources

Overview

- IBM Spectrum Scale, like any distributed software, depends highly on the network infrastructure in order to operate efficiently.
- The goal of this presentation is to provide a description of the various network traffic flows involved in the IBM Spectrum Scale environment.
- Network designers can use this information to design a suitable network for the IBM Spectrum Scale environments

Types of network traffic in IBM Spectrum Scale environment

- In general, network traffic in IBM Spectrum Scale can be divided into 3 major types:
  - Data/Metadata Traffic:
    This type of traffic is mostly around actual data movement between various IBM Spectrum Scale components. It might travel over TCP/IP or use RDMA depending on the network type and protocol being used.
    Examples include: NSD traffic, GNR synchronization, public NAS protocol traffic, AFM replication traffic , external pools traffic etc.
  - Control traffic:
    This type of traffic consists of messages (usually small payloads) that are being used for control purposes. It includes both internal and external traffic (internal traffic involves control traffic between IBM Spectrum Scale components, while external traffic involves control traffic between IBM Spectrum Scale and external entities).
    Examples includes: Token traffic, disk leases traffic, encryption related key traffic, quota management traffic, monitoring traffic, CTDB traffic, configuration management traffic, authentication traffic etc.
  - Adminitration traffic:
    This type of traffic is around administrative operations that are being performed on an IBM Spectrum Scale environment
    Examples includes: remote shell traffic, Web GUI traffic (external), REST administration traffic etc.
- Different components are using the above mentioned traffic type in different ways. Thus, we will try to describe each traffic type on a per component basis

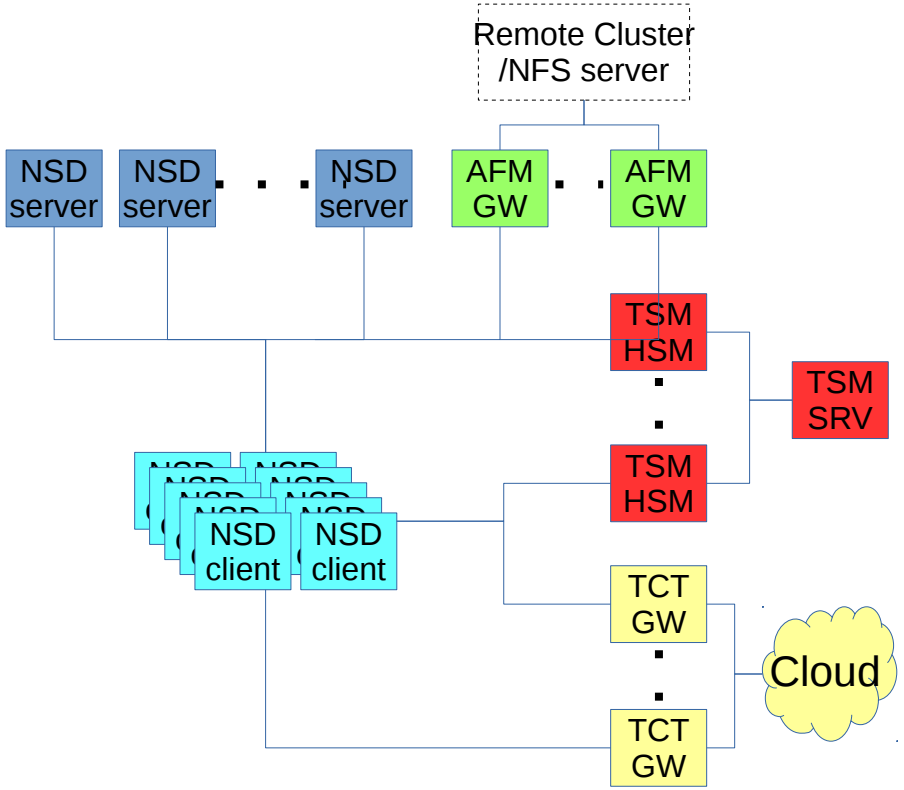
Note: In the last couple of years, many new features were introduced on top of the traditional GPFS product, which made IBM Spectrum Scale more feature-rich. Many of those features required introducing new types of network flows.

IBM Spectrum Scale component - “Core”

- The traditional GPFS is the core component of IBM Spectrum Scale.
- All the non “core” IBM Spectrum Scale components essentially use the “core” components while enriching its capabilities (access using standard protocols, management capabilities etc.) . Thus, the flows discussed in this section apply to the other components as well.
- Some traffic flows depend on the features being used (for example: encryption, quotas etc.).
- Some traffic flows are affected by the configuration being used (for example: replication traffic).

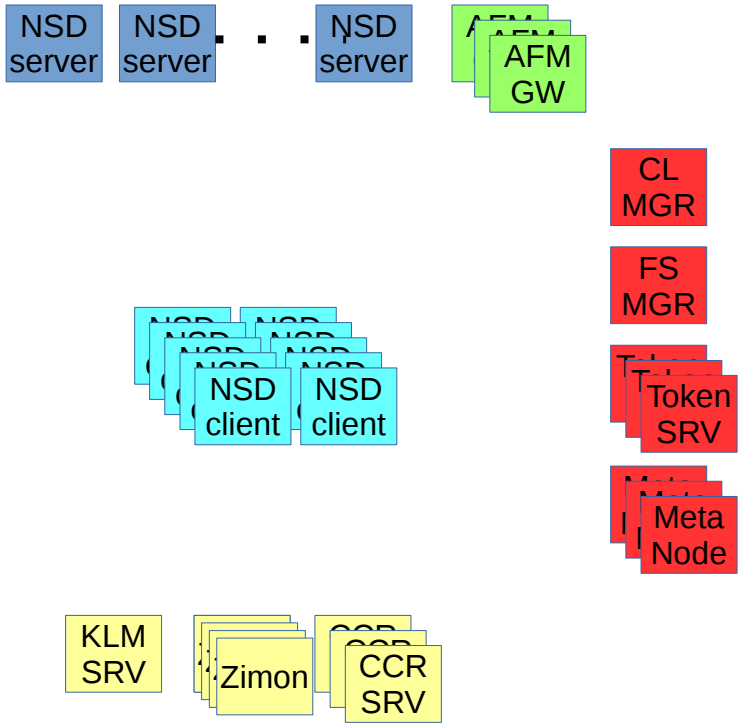
IBM Spectrum Scale components - “Core”
Data traffic

- The basic data traffic type in “Core” environment is that data transfer between the NSD servers and various clients (which might have other roles, like protocol nodes, TSM nodes, AFM GW, TCT nodes etc.). In the context of this document, Data includes filesystem metadata as well.
- Data traffic is using the NSD protocol (Network Shared Disk) over either TCP/IP and/or RDMA (over Ethernet – a.k.a. RoCE, over IB and over OPA). RDMA protocol is considered more efficient, especially for large I/O sizes.
- The required characteristics of the data channel highly depend on the customer workload (throughput oriented, latency oriented etc.). While metadata workload is usually latency-sensitive.
- For sequential workloads, data messages size may be as large as the file system block size.
- When using IBM Spectrum Scale sync replication, the client is responsible for writing multiple copies. Thus, it is required to take those into account as well (2X/3X writes for 2/3 replicas). For FPO configurations, where enableRepWriteStream is enabled, the first NSD server will write the third replica instead of the client.
- Other data paths, which are still considered “core” are the ones related to various features around moving data out of/into “IBM Spectrum Scale” environments:
  - AFM GW: Read/write (configuration dependent) data to/from external sources (either remote GPFS cluster or generic NFS server)
  - Spectrum Protect HSM: When using Spectrum Protect as an external pool for ILM, data will move to/from IBM Spectrum Scale to the IBM Spectrum Protect infrastructure.
  - TCT: Transparent Cloud Tiering used as an external pool as well, data will be moved to/from the external cloud/Object infrastructure



IBM Spectrum Scale components - “Core”
Control traffic

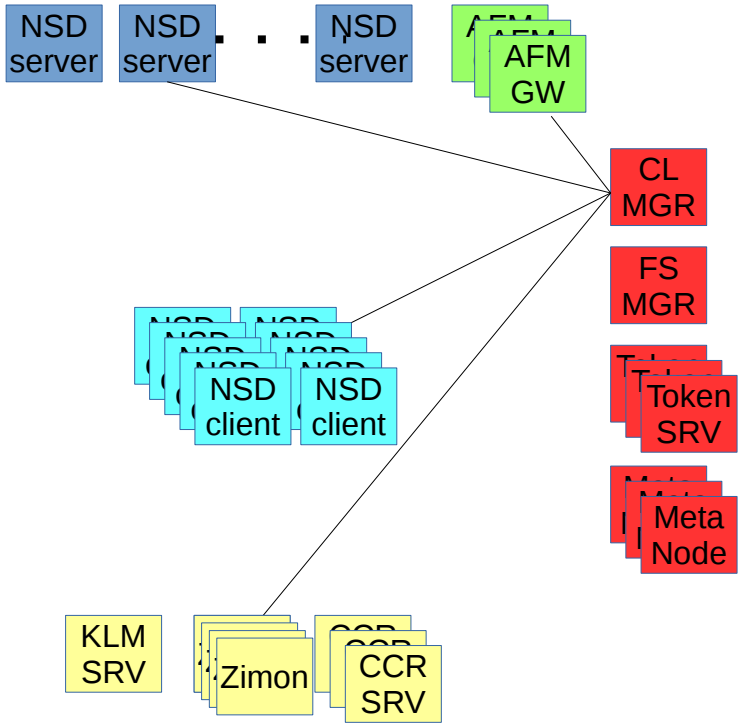
- Control traffic in IBM Spectrum Scale environments can be divided into three major types:
  - Cluster “well being” - i.e. disk leases (“heartbeat”)
  - Data access or consistency management (Tokens, quotas, allocation etc.)
  - Configuration or feature related (key management, Zimon collectors, configuration management, AFM related RPCs etc)
- Most of these types of communication are latency sensitive (i.e. slow response time will affect performance) however, some of them,especially the “well being” ones are less latency sensitive, but highly impact the availability of nodes in the cluster if message delay exceeds specific values (e.g. heartbeat timeouts).
- Note: In most cases, a node can play multiple roles.



IBM Spectrum Scale components - “Core”
Control traffic

“Cluster well being” - a.k.a disk leases traffic

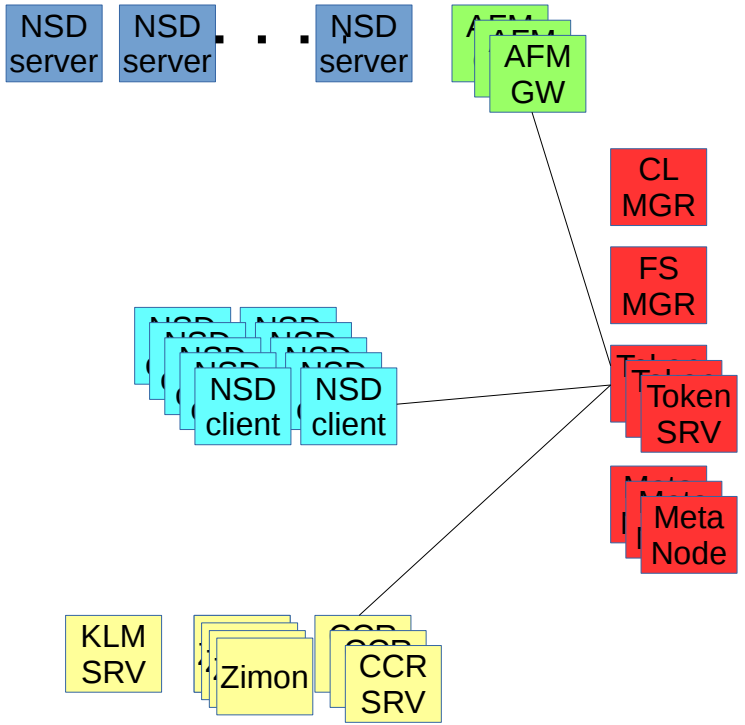
- In each cluster, the cluster manager manages the disk leases. The cluster manager is automatically elected from the list of “quorum nodes”.
- Each node (regardless of its role) needs to renew its lease with the cluster manager server (dynamically elected) at regular intervals (35 sec. By default).
- If a node fails to renew its lease, the cluster manager will try to ping the “suspected node” before expelling it.
- Another expel case might take place if a node can’t talk to another node. In that case, it will ask the CL mgr to expel the node. The CL MGR will decide which node needs to be expelled
- All nodes in the local cluster (and potentially on remote clusters) participate in the lease-renewal mechanism, regardless of their role.



IBM Spectrum Scale components - “Core”
Control traffic

“Data access/consistency management”

- As a distributed filesystem, IBM Spectrum Scale needs some mechanisms in order to assure data consistency as well as capacity management. We describe those cases below:
  - Tokens:
    Overview:
    One of the basic constructs of IBM Spectrum Scale, as a parallel fs, is the use of tokens in order to maintain consistency. Essentially, in order to perform an operation on a filesystem object (file/directory etc.) a relevant token is required (for reading, writing, caching etc.).
    Workflow:
    At least one token server is automatically selected from the list of “manager” nodes. The token servers manage the tokens, and each client (regardless of its role) needs to contact a token server. The token servers “divide” the object responsibility between them based on inode number, thus achieving load balancing and better resiliency.
    Network Requirements:
    In general, token traffic is based on small RPC messages, which are mostly latency sensitive (i.e. not throughput oriented). Slow response time (due to latency, network congestion etc.) might result in “hangs” or “hiccups” from user/application perspective

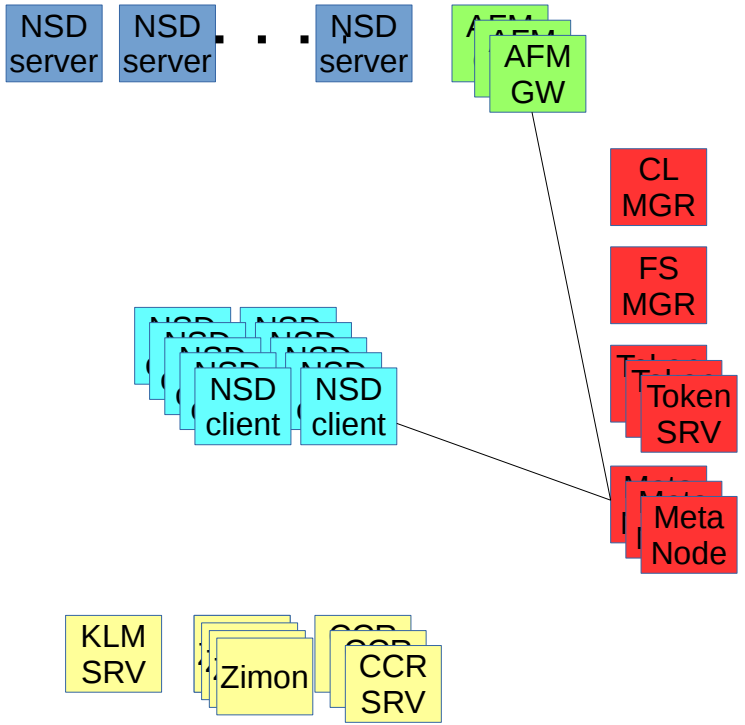


IBM Spectrum Scale components - “Core”
Metadata traffic in presence of file sharing

“Data access/consistency management”

- Metanode**:**

  Overview:
  A corner case in token management (in order to achieve better performance) is the use of a “metanode”.
  One of the challenges in multi-node access to the same object is the ability to maintain metadata consistency. While in theory, the common token system can be used, updating (or querying) object metadata might result in many token “steals”. Thus, we use a slightly different mechanism, in which one node (usually the first node that opened the object) will act as a “metadata node” for that object. Any other node that would like to update/query the object’s metadata (inode fields) will talk to that node – thus achieving better scalability for multiple objects.The metanode will be the only one updating the object’s metadata through the NSD server.
  Workflow:
  The main difference in workflow when considering the metanode role is that there will be metadata traffic not only between NSD clients and server, but also directly between different NSD clients.
  Network Requirements:
  Metanode traffic is similar to generic token traffic, i.e. latency-sensitive for small messages.

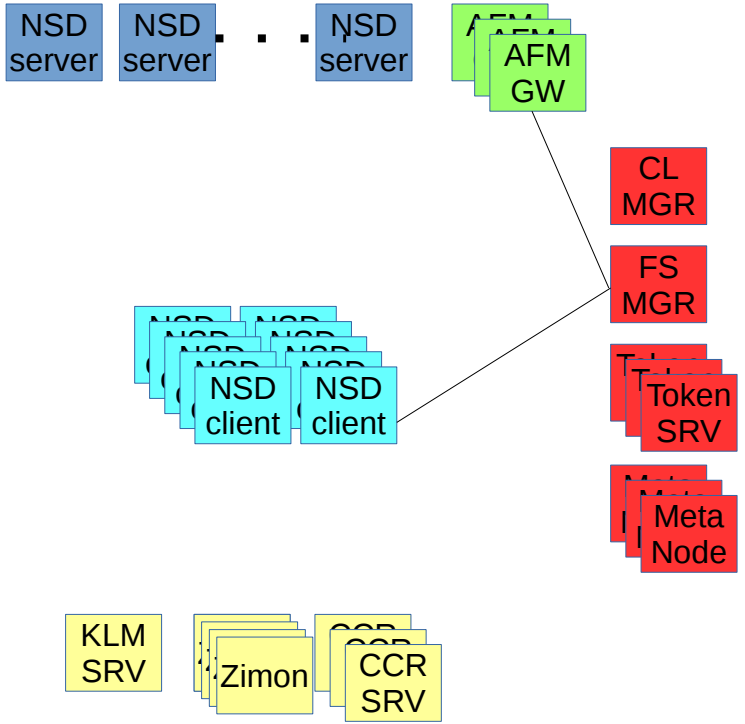


IBM Spectrum Scale components - “Core”
Control traffic

“Data access/consistency management”

- **Filesystem allocation and quota:**

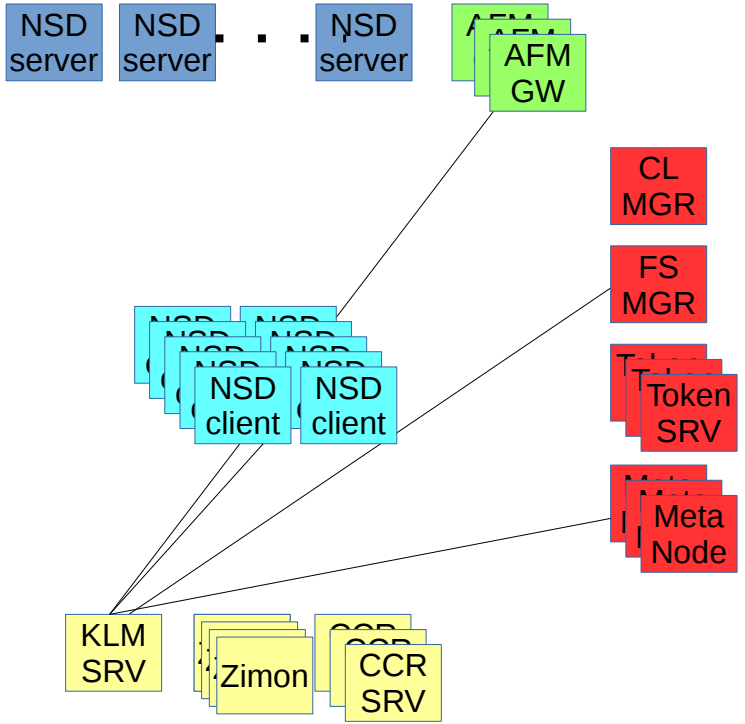
  Overview:
  Managing block and inode allocation in highly distributed filesystem is a big challenge. While there are similarities between standard allocation and quotas, the main difference is that quotas operates at finer granularity (there are separate quota for each user/group/fileset etc.) , Thus different mechanisms are used that affect the communication impact on both.
  Workflow:
  For filesystem based block/inode allocation, a set of predefined allocation regions are used. Thus, when a node needs block or inode allocation, it just needs to be assigned with an available region. The communication impact is relatively low until the region is used or “Stolen” by another node. The FS MGR manages the region allocation.
  Quota is a bit more challenging as it requires much more frequent messaging. Thus, an eventual consistent usage was implemented. Each node will get a “share” of blocks/inodes for the relevant quota entity (autotuned post 4.1.1). The quota manager, running on the FS MGR, will manage those shares assignment upon request.
  Network Requirements:
  Block/inode allocation is also based on small messages and thus are latency sensitive. While regular allocation might not be affected by slowness due to the region based approach, quotas allocation might affect write/create performance.
  In both cases, all nodes will contact the respective FS MGR in order to get allocation regions and/or quota shares.



IBM Spectrum Scale components - “Core”
Control traffic

“Configuration/feature related”

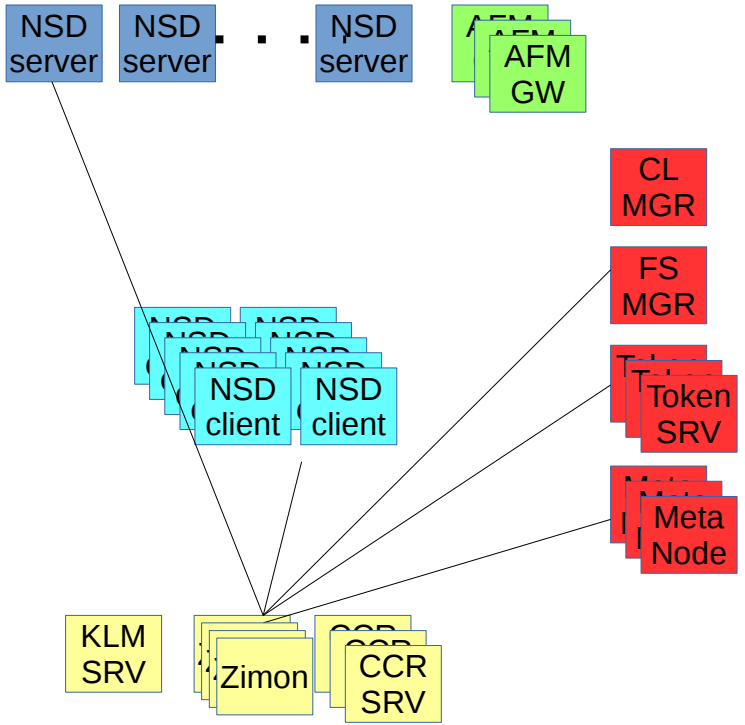
- Key management:
  Overview:
  When IBM Spectrum Scale introduced the native filesystem encryption, a new dependency (or communication flow) was introduced, the ability to talk to a key server (currently either SKLM or Vormetrics)
  Workflow:
  Since any node in the environment (either local or remote cluster) might need to access encrypted data, all nodes needs to have access to a key server.
  While the nodes will cache the keys for some time (configurable) not being able to fetch keys from the key server might result in data access error
  Network Requirements:
  Key fetching from key server/s is mostly around small messages to the designated set of servers. As mentioned above, all nodes accessing encrypted data need to have access to those servers



IBM Spectrum Scale components - “Core”
Control traffic

“Configuration/feature related”

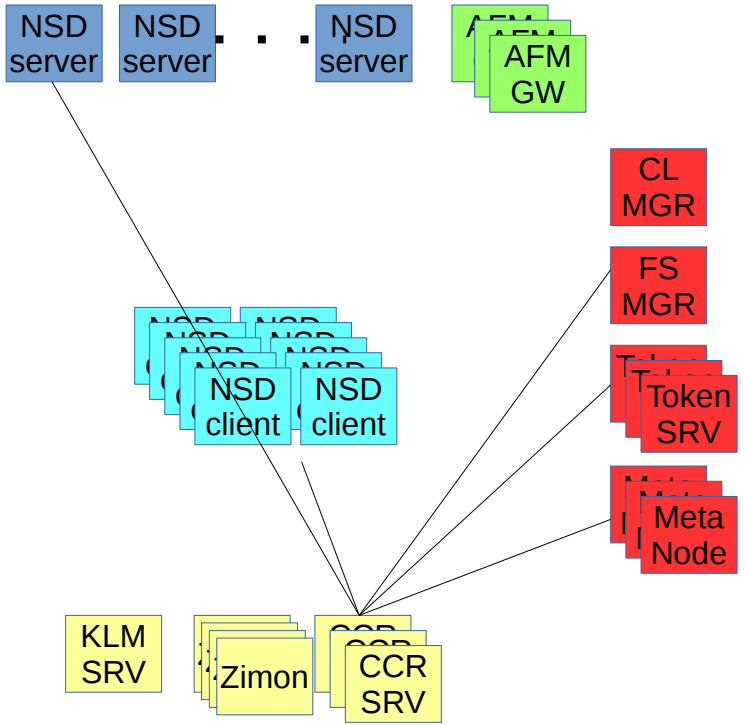
- Performance collection (zimon):
  Overview:
  Starting with IBM Spectrum Scale 4.1.1 a performance collection solution is included with the product. It is based on the zimon technology. Zimon collects a variety of performance related metrics to be later presented using either IBM Spectrum Scale GUI, Grafana (using a bridge) or CLI (using the mmperfmon command)
  Workflow:
  Like most performance monitoring systems, zimon (starting with IBM Spectrum Scale 4.2) can potentially use a federated structure of reporters (every node) and collectors (specifically defined nodes). Each node reports to its designated collector allowing the various collectors to be queried for the collected data. The collectors know about each other – thus able to satisfy queries for performance data stored on other collectors.
  Network Requirements:
  Zimon reporting is also based on relatively small messages, flowing between monitored nodes to their designated collector. In order to achieve HA one client might report to more then one collector.
  That said, its important to note that zimon traffic is not in the “data path” meaning, lack of ability to report in a timely fashion will result in some performance data missing, but wouldn’t affect actual data access (i.e. no user impact, only admin impact).



IBM Spectrum Scale components - “Core”
Control traffic

“Configuration/feature related”

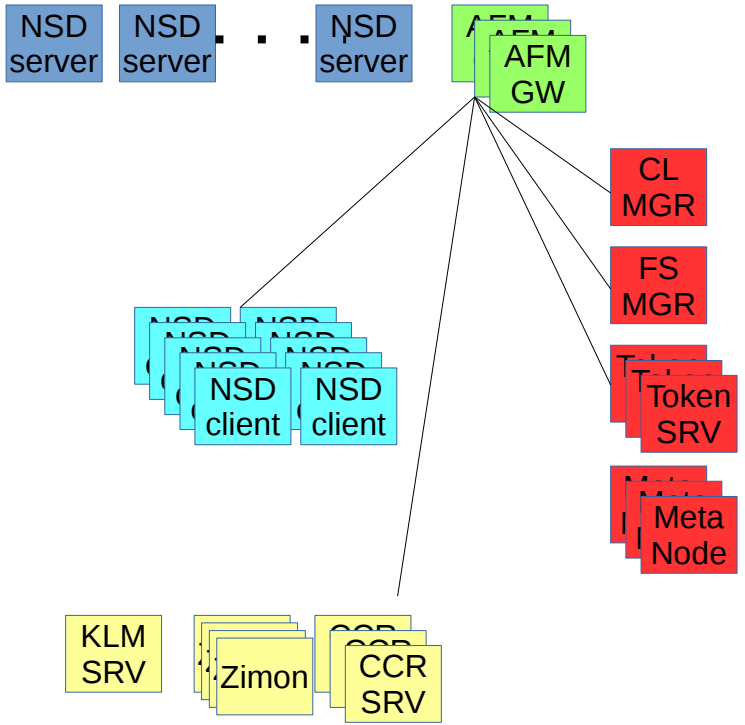
- Configuration Management (CCR):
  Overview:
  In the past, GPFS used two designated configuration server nodes to manage the authoritative version of the cluster configuration. Starting with version 4.1 a new Cluster Configuration Repository (CCR) was introduced. Today, all quorum nodes act as a CCR nodes, meaning that they manage the distributed configuration state of the cluster. CCR also allows using multiple configuration files – thus allowing IBM Spectrum Scale configuration repository to manage much more info (including protocols configuration, authentication configuration etc.).
  Workflow:
  In general, there are two major operations that can be done on configuration that are being managed by CCR: update and query. Both can be done from any node – but will change (and distribute the changes) to all CCR nodes in the cluster and potentially (depending on the specific configuration file) to all cluster nodes.
  On update, the whole file will be pushed to the CCR nodes – and while the file is usually small, it might grow to several MB on large clusters
  Network Requirements:
  CCR usually use small messages as well, from all cluster nodes. Special nodes that utilize the CCR more then others (protocol nodes, GNR nodes, GUI etc) might introduce more traffic then others.



IBM Spectrum Scale components - “Core”
Control traffic

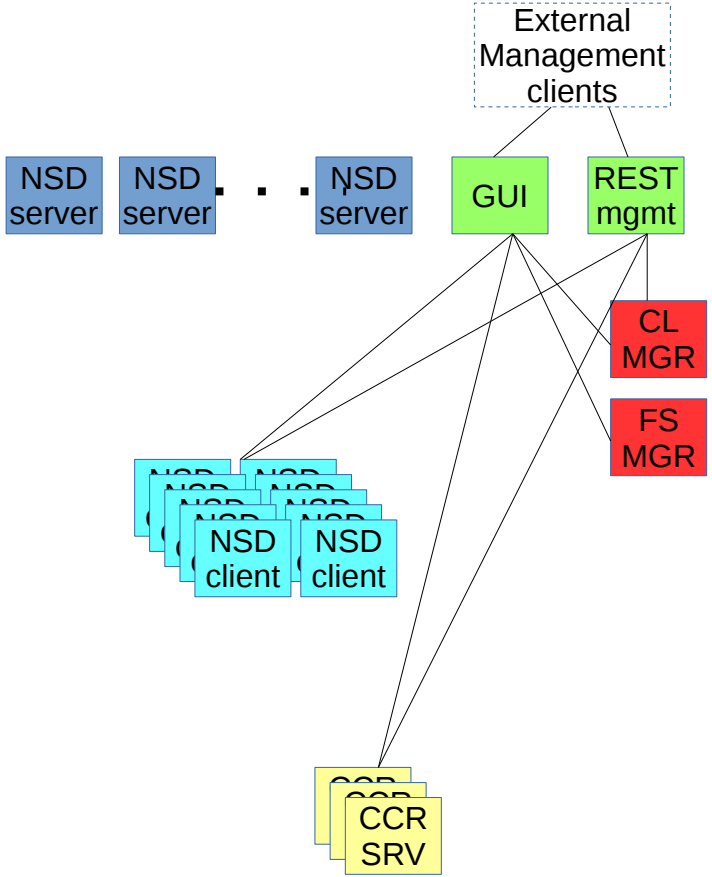
“Configuration/feature related”

- AFM related RPCs:
  Overview:
  While the data traffic part of AFM was discussed earlier, AFM also uses client to AFM gateway RPCs in order to let the GW know about filesystem operations that need to be replicated by the GW.
  Workflow:
  When a client node (any client that does I/O on an AFM fileset) perform read/write operation on a filesystem object – it send special RPC to the AFM GW so the GW can either add the specific op to the fileset queue (for write/creates etc.) or validate/fetch that data on reads.
  In order to perform the various operations, the AFM GW node might require other type of traffic, data or control in order to actually perform the required operations
  Network Requirements:
  The AFM related RPCs are small messages, as only the op itself is being transmitted, not the data itself.
  The traffic might flow to/from any node that access the AFM fileset (on either local or remote clusters).



IBM Spectrum Scale components - “Core”
Administration traffic

- Administration traffic in the core components can be divided into internal traffic (i.e. traffic that is used to perform operations on the various cluster nodes) and external traffic (traffic used by external entities in order to “talk” to components performing operations on their behalf).
- The first type of traffic mostly uses remote shell commands (ssh on modern systems). Some parts of internal traffic also use special RPCs that replaced the remote shell commands on older versions of GPFS (in order to minimize the dependency on remote shell). Those operations are mostly around distributing config files on new nodes, NSD creation etc. Some customers are using dedicated “management” network in order to perform those (admin interface).
  Unless otherwise defined (using the adminMode config option) any node in the cluster might be the source of those operations, in most cases, some other node will perform the actual operation on the requester behalf (cluster manager/filesystem manager etc.).
- The second type (external administration) is mostly around web based GUI access and/or the new REST interface to IBM Spectrum Scale commands.
- Both operations are not in the data path and usually being used by interactive commands (thus, extremely long delays will cause complaints by administrators), but their performance requirements are not critical.



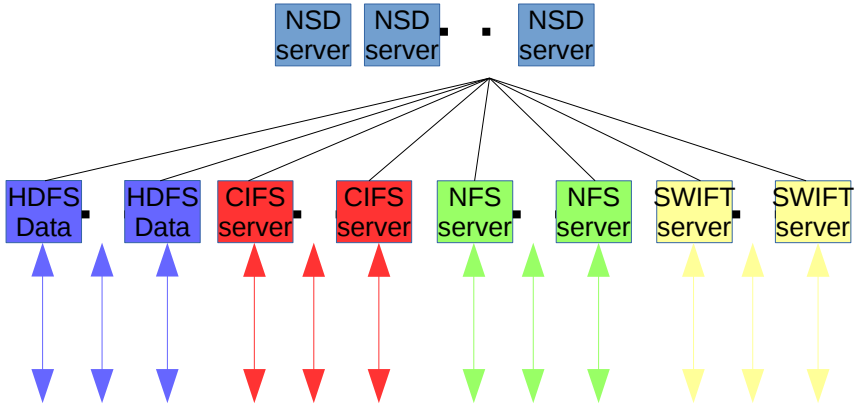
“Protocols”

IBM Spectrum Scale components - “Protocols”

- The “protocols” component of IBM Spectrum scale provides the ability to access data stored on various filesystems using standard protocols.
- Today, the supported protocols are: NFS, CIFS, Swift (Object), HDFS and iSCSI (boot only) .
- “protocol nodes” are nodes that are running the various services. From IBM Spectrum Scale perspective they are usually “client” nodes (function wise, not licensing wise) – meaning that they access the data as any other IBM Spectrum Scale client node.
- Thus, on one hand they utilize all the data/control/management traffic as mentioned in the “core” section, but on the other hand, uses other protocols data/control traffic (protocol dependent).
- Some protocols require special control protocol for cluster awareness (CIFS) and most protocols also require authentication control traffic (usually to external authentication server/s).

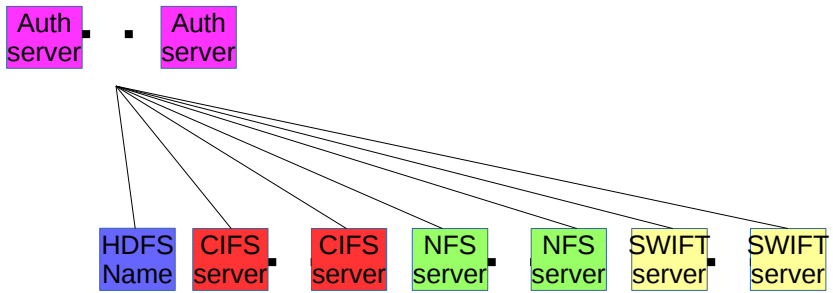
IBM Spectrum Scale components - “Protocols”
Data traffic

- As mentioned earlier, protocol nodes are using the core data traffic on their “backend” in order to talk to the NSD servers.
- On the “frontend” protocol nodes are using the relevant protocol data path.
- Depending on the access pattern and dataset the traffic might be throughput oriented or latency oriented.
- Some protocols might assign different roles to different nodes (e.g. HDFS datanode vs. namenode).
- It is advised not to use the same interfaces for both IBM Spectrum Scale (backend) traffic and protocols (frontend) traffic.



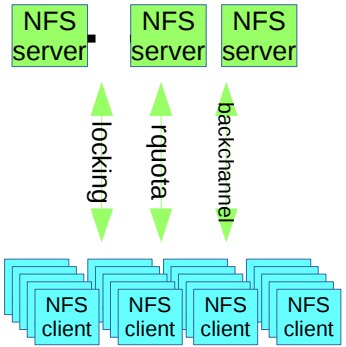
IBM Spectrum Scale components - “Protocols”
Control traffic

- As mentioned earlier, protocol nodes are using the same control traffic on their “backend” as any IBM Spectrum Scale client node.
- On the protocols specific part, there are both common control traffic (usually authentication) and potentially protocol specific control traffic:
  - Authentication: Most protocols (unless using local authentication) will contact the configured external authentication servers in order to get authentication related information. For the most part those are relatively small, latency sensitive operations



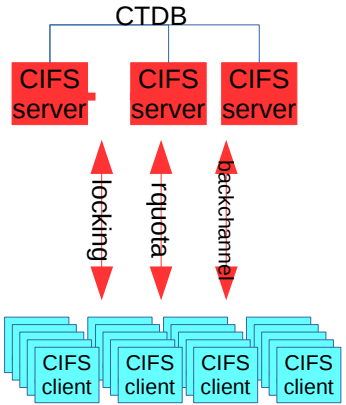
IBM Spectrum Scale components - “Protocols”
Control traffic

- Protocol Specific control traffic
  - NFS:
    IBM Spectrum Scale uses Ganesha NFS server for providing NFS services.
    Back-end:
    Ganesha doesn’t use any special internode communication, it relies on GPFS as a clustering mechanism.
    Front-end:
    For the most part, the NFS protocol is includes mixed data and control traffic. Control traffic on NFS includes locking (separate on V3 and integrated on V4), delegation backchannel (V4 – not yet supported) and rquota protocol.
    All of the front end control data is mostly around small messages somewhat latency sensitive (application dependent).



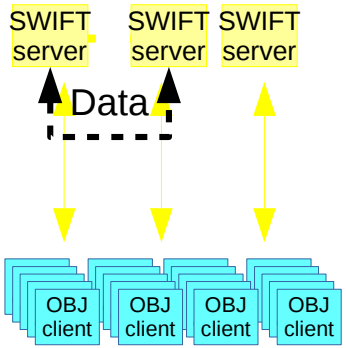
IBM Spectrum Scale components - “Protocols”
Control traffic

- Protocol Specific control traffic
  - CIFS:
    In order to provide CIFS services, IBM Spectrum Scale is using the SAMBA software together with the CTDB clustering software.
    Back-end:
    In order to manage the CIFS locking state inside the cluster, CTDB needs to communicate between the nodes. The traffic is based on latency-sensitive small messages .
    Front-end:
    For the most part, the CIFS protocols mix both data and control protocol – so its a bit hard to differentiate between them. Control traffic includes locking and callback channel (i.e. when the server contacts the client to break oplocks etc.). Both largely depend on the specific workload and dataset.



IBM Spectrum Scale components - “Protocols”
Data traffic

- Protocol Specific control traffic
  - SWIFT/S3:
    In order to provide Object based services, IBM Spectrum Scale is using OpenStack Swift software with some enhancements in order to provide better S3 support.
    Back-end:
    Currently, the only traffic on the backend network with the object implementation is the same traffic as the regular “core” components.
    Front-end:
    The object implementation is using several data and control messages over the public network:
    - **Data:** With object protocol data, a client requests a read/write operation to a protocol node over the front end (CES) network. With traditional Swift mode, that request may be processed by the same protocol node or passed to a different protocol node for processing. With unified file and object access mode (Swift on File), the request is always processed by the protocol node that received the client request. The front end (CES) network is used for passing requests between protocol nodes



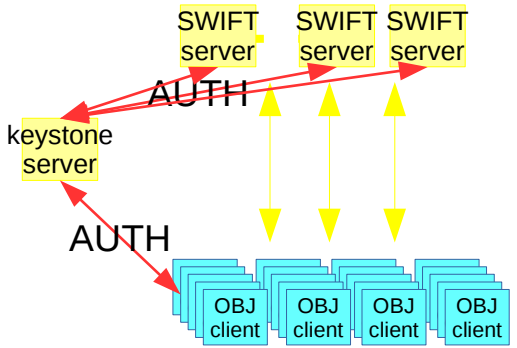
IBM Spectrum Scale components - “Protocols”
Control traffic

- Protocol Specific control traffic
  - SWIFT/S3 (Continued)

    Control: Control traffic in Swift is mostly around authentication traffic, and somewhat depends on the chosen configuration:

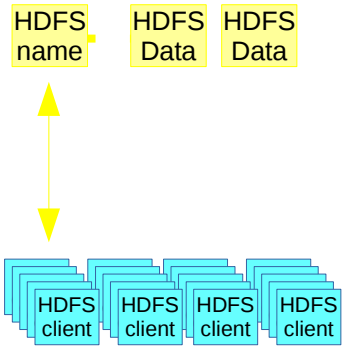
    - If the keystone authentication service is being provided by the protocol nodes (the common case), then clients will contact the keystone node in order to validate the user and get security token.
      When using Swift protocol, the server will cache the token using memcached based on the token TTL, in order to reduce the authentication traffic, when using S3, the server will not cache any tokens.
    - When clients contact a protocol node with their security token, the node will contact the keystone server in order to validate the token. In some cases, the keystone server might be running on different node or on a 3rd party node (when using external keystone).

  - **Note: Currently, all the authentication traffic will take place using the front-end (CES) IPs and not the back-end network**



IBM Spectrum Scale components - “Protocols”
Control traffic

- Protocol Specific control traffic
  - HDFS:
    For Hadoop-like workload (or applications that are using the DFS API in order to access data, IBM Spectrum Scale implements the transparent Hadoop connector. The control data is being managed by a single “namenode” at a time, which provides the client with info which data nodes to get the actual data from.
    Back-end:
    There is no special back-end data going on for the hadoop transparent connector.
    Front-end:
    Today, a single node act as the namenode at any given time. Clients will first contact this node, using the standard HDFS RPCs in order to query location of specific blocks.
    As with most control protocols, those are small messages, relatively latency sensitive (since actual data is usually large, the latency might not be that critical).



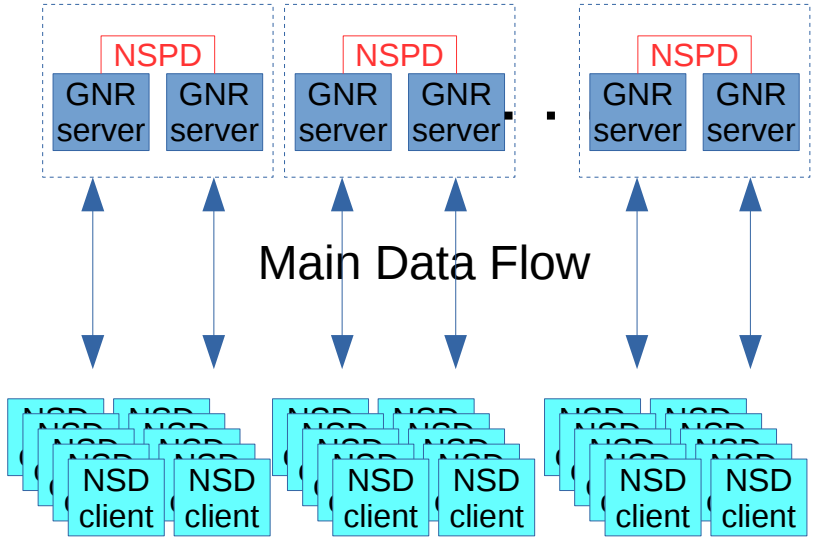
“GNR”

IBM Spectrum Scale components - “GNR”

- GPFS Native Raid (a.k.a IBM Spectrum Scale RAID) is a software based RAID implementation that is being used with several storage product, for example Elastic Storage Server (ESS) from IBM.
- From “core” IBM Spectrum Scale perspective, GNR node are considered NSD servers where “below” the NSD layer we have the GNR layer itself that takes care of the physical disks management and data protection using declustered RAID technology.
- That said, the GNR layer itself present several new network related flows in order to provide efficient write caching as well as monitoring of the partner node in each GNR building block.

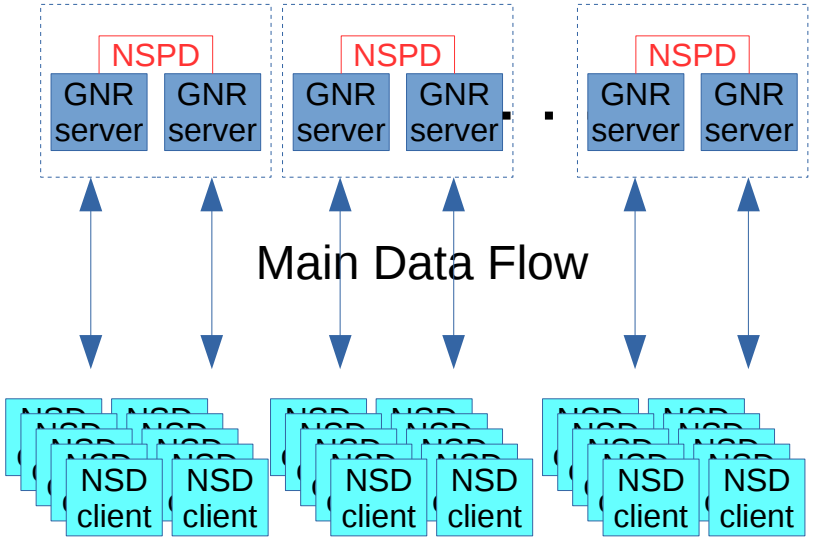
IBM Spectrum Scale components - “GNR”
Data traffic

- As mentioned earlier, GNR nodes also act as NSD servers, thus the main data flow that is going on with GNR is reading/writing to/from clients. That part is discussed in the “core” component. That said, the high performance that GNR nodes usually provide, require adequate network bandwidth in order to really utilize GNR nodes capabilities.
- Another special type of traffic we have with GNR is NVRAM replication. Essentially, GNR uses the internal NVRAM on the nodes in order to implement a “logTip”, as an extremely fast small write cache (technically, its an append to circular log) and for internal GNR metadata operations. Since the NVRAM is internal to each server, a special protocol (NSPD) is used in order to replicate those operations into the building block “partner”. The replication is based on small messages which are highly latency sensitive (higher latency will impact small write performance). Under some workload, it might make sense to separate this traffic using fast interconnect (e.g. IB) in order to enhance the performance and avoid the competition with the main data stream.



IBM Spectrum Scale components - “GNR”
Control traffic

- Much of GNR’s control traffic is the same as the rest of the “core” components. That said, due to the special need to manage large number of disks there are some special control traffic going on in the background in order to monitor each building block partner.
- The nature of this traffic is around relatively small messages, but since they are performed in the background, latency if not that critical for those.



Other resources

Other resources

- List of ports being used by IBM Spectrum Scale components
  https://ibm.biz/BdixM4