RuntimeProxy源码分析

文章分析主要分为静态分析和 动态分析，由于runtimeproxy模块默认是containerd，所以本次只单用containerd做分析，不分析docker运行时，因为docker逻辑和containerd逻辑差不多，所以单分析containerd就很有代表性了。

一、分析环境

koordnator软件版本

```
v1.4.0
```

运行环境

```
ubuntu21.04
```

二、启动参数分析

参数名称	描述	默认值
koord-runtimeproxy-endpoint	runtimeproxy启动后会监听这个endpoint，如果有cri请求到达，会中转到 remote-runtime-service-endpoint	/var/run/koord-runtimeproxy/runtimeproxy.sock
remote-runtime-service-endpoint	连接容器运行时，比如docker.sock或者containerd.sock,用来操作容器运行时	/var/run/containerd/containerd.sock
backend-runtime-mode	后台运行模式 (Docker、Containerd)	Containerd
runtime-hook-server-key		
runtime-hook-server-val		

三、静态代码分析

runtimeproxy 核心功能只有一句话，就是拦截发往CRI的请求，然后转发给koordlet做处理，然后收到koordlet的响应结果后继续转发给CRI

官网相关资料参考地址:

```
https://koordinator.sh/zh-Hans/docs/designs/runtime-proxy/
```

1、config-manager模块分析

config-manager用来管理runtime插件的配置，在配置文件发生变化的时候可以自动更新 配置

监听目录为

```
/etc/runtime/hookserver.d/
```

监听配置文件必须为.json后缀,例如文件/etc/runtime/hookserver.d/koordlet.json，demo内容

```
{
    "remote-endpoint": "/var/run/koordlet/koordlet.sock",
    "failure-policy": "Ignore",
    "runtime-hooks": [
        "PreRunPodSandbox",
        "PreCreateContainer",
        "PreStartContainer"
    ]
}
```

failure-policy: 调用插件失败时的策略，失败或忽略，默认为忽略。 remote-endpoint: KoordRuntimeProxy 与插件对话端点，由插件生成。

failure-policy 目前支持俩值Fail 和 Ignore，具体代码定义:

```
const (
    // PolicyFail returns error to caller when got an error cri hook server
    PolicyFail FailurePolicyType = "Fail"
    // PolicyIgnore transfer cri request to containerd/dockerd when got an
error to cri serer
    PolicyIgnore FailurePolicyType = "Ignore"
    // PolicyNone when no Policy configured. Proxy would ignore errors for
PolicyNone like PolicyIgnore.
    PolicyNone = ""
)
```

核心是使用linux的inotify机制，监听目录，当目录下有文件发生变化的时候，会触发回调函数，执行相应的操作。linux inotify机制的详细介绍可以参考linux inotify机制

koordinator 核心实现代码

pkg/runtimeproxy/config/config_manager.go

创建inotify 事件，位于Manager->Run中

```
watcher, err := fsnotify.NewWatcher()
```

添加监听文件 Manager->registerFileToWatchIfNeed

```
func (m *Manager) registerFileToWatchIfNeed(file string) error {
    fileInfo, err := os.Stat(file)
    if err != nil {
        return err
    }
    stat, ok := fileInfo.Sys().(*syscall.Stat_t)
    if !ok {
        return fmt.Errorf("fail to get file ino: %v", file)
    }
    m.Lock()
    defer m.Unlock()
    config, exist := m.configs[file]
    if exist && config.fileIno == stat.Ino {
        return nil
    }
    if exist && config.fileIno != stat.Ino {
        m.watcher.Remove(file)
        klog.Infof("remove previous file %v with inode number %v", file,
config.fileIno)
    }
    m.watcher.Add(file)
    m.configs[file] = &RuntimeHookConfigItem{
        filePath: file,
        fileIno:  stat.Ino,
    }
    klog.Infof("add new watching file %v with inode number %v", file,
stat.Ino)
    return nil
}
```

监听配置文件变化

```
func (m *Manager) syncLoop() error {
    for {
        select {
        case event, ok := <-m.watcher.Events:
            if !ok {
                klog.Infof("config manager channel is closed")
                return nil
            }
            // only reload config when write/rename/remove events
```

```
            if event.Op&(fsnotify.Chmod) > 0 {
                klog.V(5).Infof("ignore event from runtime hook config dir
%v", event)
                continue
            }
            // should add the config file to watcher if event.Op is
fsnotify.Create
            klog.V(5).Infof("receive change event from runtime hook config
dir %v", event)
            m.updateHookConfig(event.Name)
        case err := <-m.watcher.Errors:
            if err != nil {
                klog.Errorf("failed to continue to sync %v",
defaultRuntimeHookConfigPath)
            }
        }
    }
}
```

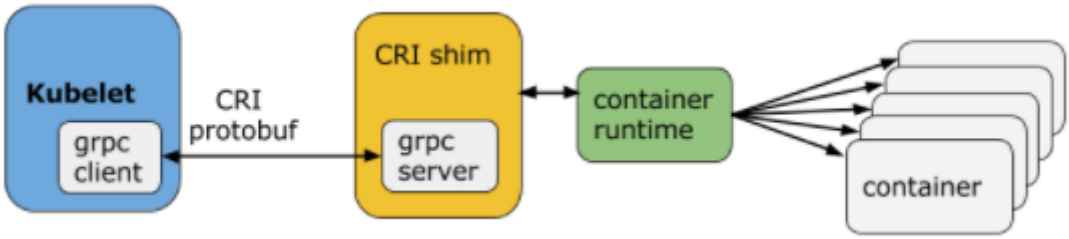
监听到配置变化后使用,更新到内存中。

```
Manager->updateHookConfig
```

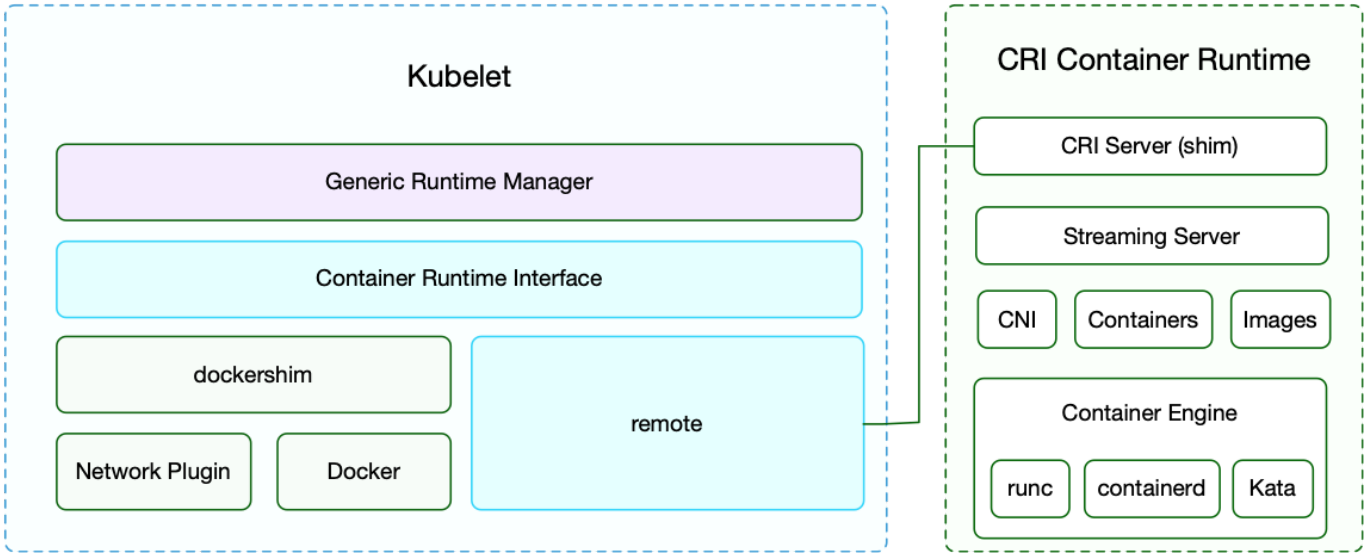
2、criServer 模块分析

CRI 简介

容器运行时插件（Container Runtime Interface，简称 CRI）是 Kubernetes v1.5 引入的容器运行时接口，它将 Kubelet 与容器运行时解耦，将原来完全面向 Pod 级别的内部接口拆分成面向 Sandbox 和 Container 的 gRPC 接口，并将镜像管理和容器管理分离到不同的服务。



采用 CRI 后，Kubelet 的架构如下图所示:



CRI 接口 CRI 基于 gRPC 定义了 RuntimeService 和 ImageService 等两个 gRPC 服务，分别用于容器运行时和镜像的管理。其定义在

```
v1.14 以以上：https://github.com/kubernetes/cri-
api/tree/master/pkg/apis/runtime
v1.10-v1.13: pkg/kubelet/apis/cri/runtime/v1alpha2
v1.7-v1.9: pkg/kubelet/apis/cri/v1alpha1/runtime
v1.6: pkg/kubelet/api/v1alpha1/runtime
```

常见CRI运行时:

CRI 容器运行时	维护者	主要特性	容器引擎
Dockershim	Kubernetes	内置实现、特性最新	docker
cri-o	Kubernetes	OCI标准不需要Docker	OCI（runc、kata、gVisor...）
cri-containerd	Containerd	基于 containerd 不需要Docker	OCI（runc、kata、gVisor...）
Frakti	Kubernetes	虚拟化容器	hyperd、docker
rktlet	Kubernetes	支持rkt	rkt
PouchContainer	Alibaba	富容器	OCI（runc、kata...）
Virtlet	Mirantis	Mirantis	Libvirt（KVM）

CRI-SERVER 源码解析

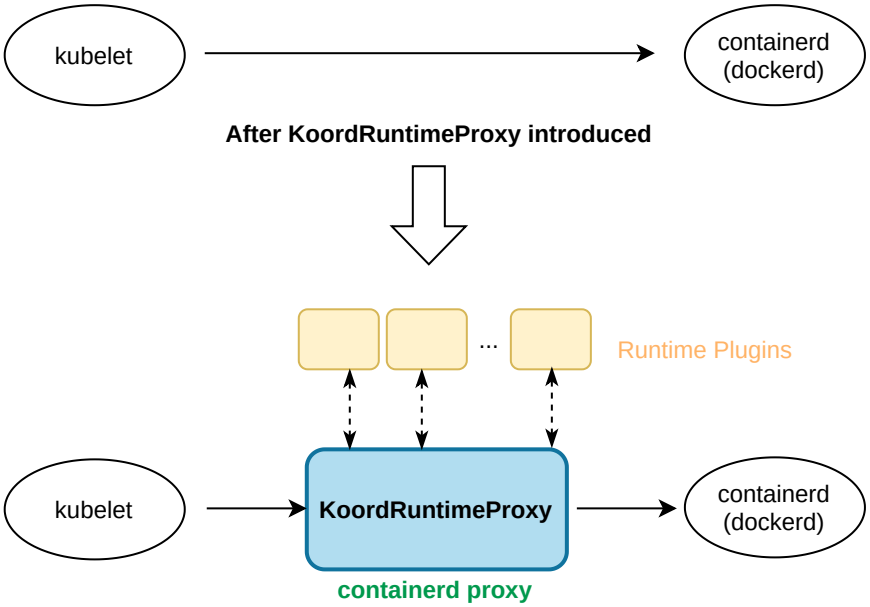
koordinator runtimeproxy的核心逻辑是使用 cri协议监听，域套接字文件，例如，文件为:

```
/var/run/koord-runtimeproxy/runtimeproxy.sock
```

然后 再和容器运行时监听的套接字文件建立连接，当runtimeproxy.sock 的server 收到 数据后，再进行一系列 intercept 然后转发到 containerd.sock，实现对容器的管控，例如，转发给的sock文件为：

```
/var/run/containerd/containerd.sock
```

整体架构图:



和容器运行时containerd 建立client连接，用来转发proxy收到的数据 核心代码位于 pkg/runtimeproxy/server/cri/criserver.go的 RuntimeManagerCriServer->initCriServer 中

```
func (c *RuntimeManagerCriServer) initCriServer(runtimeSockPath string)
(*grpc.ClientConn, error) {
    generateGrpcConn := func(sockPath string) (*grpc.ClientConn, error) {
        ctx, cancel := context.WithTimeout(context.Background(),
defaultTimeout)
        defer cancel()
        return grpc.DialContext(ctx, sockPath, grpc.WithInsecure(),
grpc.WithContextDialer(dialer))
    }
    runtimeConn, err := generateGrpcConn(runtimeSockPath)
    if err != nil {
        klog.Errorf("fail to create runtime service client %v", err)
        return nil, err
    } else {
        klog.Infof("success to create runtime client %v", runtimeSockPath)
    }

    // According to the version of cri api supported by backend runtime,
create the corresponding cri server.
    _, v1Err :=
runtimeapi.NewRuntimeServiceClient(runtimeConn).Version(context.Background(
), &runtimeapi.VersionRequest{})
    if v1Err == nil {
```

```
        c.criServer = &criServer{
            RuntimeRequestInterceptor:   c,
            backendRuntimeServiceClient:
runtimeapi.NewRuntimeServiceClient(runtimeConn),
        }
    }
    _, alphaErr :=
runtimeapialpha.NewRuntimeServiceClient(runtimeConn).Version(context.Backgr
ound(), &runtimeapialpha.VersionRequest{})
    if alphaErr == nil {
        c.criAlphaServer = &criAlphaServer{
            RuntimeRequestInterceptor:   c,
            backendRuntimeServiceClient:
runtimeapialpha.NewRuntimeServiceClient(runtimeConn),
        }
    }
    if c.criServer == nil && c.criAlphaServer == nil {
        err = fmt.Errorf("%s, %s", v1Err.Error(), alphaErr.Error())
        klog.Errorf("fail to create cri service %v", err)
        return nil, err
    }
    return runtimeConn, nil
}
```

和 containerd运行时监听的套接字文件建立好连接后，监听runtimeproxy.sock 核心代码位于 pkg/runtimeproxy/server/cri/criserver.go

```
    klog.Infof("do failOver done")

    listener, err := net.Listen("unix", options.RuntimeProxyEndpoint)
    if err != nil {
        klog.Errorf("failed to create listener, error: %v", err)
        return err
    }

    // For unsupported requests, pass through directly to the backend
    director := func(ctx context.Context, fullName string)
(context.Context, *grpc.ClientConn, error) {
        return ctx, remoteConn, nil
    }
    grpcServer := grpc.NewServer(
        grpc.UnknownServiceHandler(proxy.TransparentHandler(director)),
    )
    if c.criServer != nil {
        runtimeapi.RegisterRuntimeServiceServer(grpcServer, c.criServer)
    }
    if c.criAlphaServer != nil {
        runtimeapialpha.RegisterRuntimeServiceServer(grpcServer,
c.criAlphaServer)
    }
```

```
    err = grpcServer.Serve(listener)
    return err
```

当有请求过来的时候,会触发pkg/runtimeproxy/server/cri/runtime.go,当触发容器运行时的这些钩子的时候会触发InterceptRuntimeRequest.

```
// 运行pod沙盒
func (c *criServer) RunPodSandbox(ctx context.Context, req
*runtimeapi.RunPodSandboxRequest) (*runtimeapi.RunPodSandboxResponse,
error) {
    rsp, err := c.InterceptRuntimeRequest(RunPodSandbox, ctx, req,
        func(ctx context.Context, req interface{}) (interface{}, error) {
            return c.backendRuntimeServiceClient.RunPodSandbox(ctx, req.
(*runtimeapi.RunPodSandboxRequest))
        }, false)
    if err != nil {
        return nil, err
    }
    return rsp.(*runtimeapi.RunPodSandboxResponse), err
}

// 停止pod沙盒
func (c *criServer) StopPodSandbox(ctx context.Context, req
*runtimeapi.StopPodSandboxRequest) (*runtimeapi.StopPodSandboxResponse,
error) {
}

// 创建容器
func (c *criServer) CreateContainer(ctx context.Context, req
*runtimeapi.CreateContainerRequest) (*runtimeapi.CreateContainerResponse,
error) {
}

.............................
```

runtime-hooks: 目前有7个钩点： PreRunPodSandbox PreCreateContainer PreStartContainer PostStartContainer PreUpdateContainerResources PostStopContainer PostStopPodSandbox

KoordRunmeProxy 和 Plugins 之间的协议 Protocols

```
https://github.com/koordinator-
sh/koordinator/blob/main/apis/runtime/v1alpha1/api.proto
```

3、Intercept 模块源码分析

intercept 核心源码解析，当有请求runtimeproxy.sock的时候，会触发InterceptRuntimeRequest拦截请求然后转发给容器运行时。

```
func (c *RuntimeManagerCriServer) InterceptRuntimeRequest(serviceType
RuntimeServiceType,
    ctx context.Context, request interface{}, handler grpc.UnaryHandler,
alphaRuntime bool) (interface{}, error) {
    // 通过serviceType获取钩子信息，serviceType值为上面说的 runtime-hooks 的7个钩
子点,然后获取钩子点以及运行时的资源信息，到底是Container 还是 Pod
    runtimeHookPath, runtimeResourceType :=
c.getRuntimeHookInfo(serviceType)

    // 通过资源信息Pod 或者container 实例化Executor
    resourceExecutor :=
resource_executor.NewRuntimeResourceExecutor(runtimeResourceType)

    var err error
    if alphaRuntime {
        request, err = alphaObjectToV1Object(request)
        if err != nil {
            return nil, err
        }
    }
    // 解析请求，并且从缓存中检查容器是否故障，如果容器已经故障，则不会继续执行下面逻
辑，详细看下面的故障转移
    callHookOperation, err := resourceExecutor.ParseRequest(request)
    if err != nil {
        klog.Errorf("fail to parse request %v %v", request, err)
    }
    defer resourceExecutor.DeleteCheckpointIfNeed(request)

    //  是否需要触发钩子，如果需要则触发RuntimeHookDispatcher
    switch callHookOperation {
    case utils.ShouldCallHookPlugin:
        // TODO deal with the Dispatch response
        // 这个 c.hookDispatcher.Dispatch 是Hook的关键，会把CRI请求转发给
koordlet.sock做特殊处理，然后等待koordlet模块处理完成
        response, err, policy := c.hookDispatcher.Dispatch(ctx,
runtimeHookPath, config.PreHook, resourceExecutor.GenerateHookRequest())
        if err != nil {
            klog.Errorf("fail to call hook server %v", err)
            if policy == config.PolicyFail {
                return nil, fmt.Errorf("hook server err: %v", err)
            }
        } else if response != nil {
            if err = resourceExecutor.UpdateRequest(response, request); err
!= nil {
                klog.Errorf("failed to update cri request %v", err)
            }
        }
    }
    // call the backend runtime engine
    if alphaRuntime {
        request, err = v1ObjectToAlphaObject(request)
```

```
            if err != nil {
                return nil, err
            }
        }
        res, err := handler(ctx, request)
        responseConverted := false
        if err == nil {
            if alphaRuntime {
                responseConverted = true
                res, err = alphaObjectToV1Object(res)
                if err != nil {
                    return nil, err
                }
            }
            klog.Infof("%v call containerd %v success",
    resourceExecutor.GetMetaInfo(), string(runtimeHookPath))
            // store checkpoint info basing request only when response success
            if err := resourceExecutor.ResourceCheckPoint(res); err != nil {
                klog.Errorf("fail to checkpoint %v %v",
    resourceExecutor.GetMetaInfo(), err)
            }
        } else {
            klog.Errorf("%v call containerd %v fail %v",
    resourceExecutor.GetMetaInfo(), string(runtimeHookPath), err)
        }
        switch callHookOperation {
        case utils.ShouldCallHookPlugin:
            // post call hook server
            // TODO the response
            // 这个 c.hookDispatcher.Dispatch 是Hook的关键，会把CRI请求转发给
    koordlet.sock做特殊处理，然后等待koordlet模块处理完成
            c.hookDispatcher.Dispatch(ctx, runtimeHookPath, config.PostHook,
    resourceExecutor.GenerateHookRequest())
        }
        // 是否需要加工响应数据，返回给容器运行时
        if responseConverted {
            res, err = v1ObjectToAlphaObject(res)
            if err != nil {
                return nil, err
            }
        }
        return res, err
    }
```

RuntimeHookDispatcher 的 Dispatch是runtimeproxy代码的核心，通过拦截请求转发给/var/run/koordlet/koordlet.sock，从而使koordlet做特殊处理，下面对Dispatch核心模块做分析。

核心代码位于pkg/runtimeproxy/dispatcher/dispatcher.go

当触发Dispatcher后，通过

```
hookServers := rd.hookManager.GetAllHook()
```

获取全部配置信息，由于存在另一个协程自动更新配置，所以内部实现带锁

```
for _, hookServer := range hookServers {
    for _, hookType := range hookServer.RuntimeHooks {
        // 是否是要处理的 runtime钩子点
        if !hookType.OccursOn(runtimeRequestPath) {
            continue
        }
        // 钩子阶段是否是配置文件中要处理的阶段
        if hookType.HookStage() != stage {
            continue
        }
        // 从koordlet客户端连接池中和koordlet.sock建立一个连接
        client, err := rd.cm.RuntimeHookServerClient(client.HookServerPath{
            Path: hookServer.RemoteEndpoint,
        })
        if err != nil {
            klog.Errorf("fail to get client %v", err)
            continue
        }
        // currently, only one hook be called during one runtime
        // TODO: multi hook server to merge response
        // 派遣请求给koordlet
        rsp, err := rd.dispatchInternal(ctx, hookType, client, request)
        if err != nil {
            return nil, err, hookServer.FailurePolicy
        }
        return rsp, err, hookServer.FailurePolicy
    }
}
```

具体派遣的钩子点:

```
func (rd *RuntimeHookDispatcher) dispatchInternal(ctx context.Context,
hookType config.RuntimeHookType,
    client *client.RuntimeHookClient, request interface{}) (response
interface{}, err error) {
    switch hookType {
    case config.PreRunPodSandbox:
        return client.PreRunPodSandboxHook(ctx, request.
(*v1alpha1.PodSandboxHookRequest))
    case config.PostStopPodSandbox:
        return client.PostStopPodSandboxHook(ctx, request.
(*v1alpha1.PodSandboxHookRequest))
    case config.PreCreateContainer:
        return client.PreCreateContainerHook(ctx, request.
```

```
(*v1alpha1.ContainerResourceHookRequest))
    case config.PreStartContainer:
        return client.PreStartContainerHook(ctx, request.
(*v1alpha1.ContainerResourceHookRequest))
    case config.PreUpdateContainerResources:
        return client.PreUpdateContainerResourcesHook(ctx, request.
(*v1alpha1.ContainerResourceHookRequest))
    case config.PostStartContainer:
        return client.PostStartContainerHook(ctx, request.
(*v1alpha1.ContainerResourceHookRequest))
    case config.PostStopContainer:
        return client.PostStopContainerHook(ctx, request.
(*v1alpha1.ContainerResourceHookRequest))
    }
    return nil, status.Errorf(codes.Unimplemented, fmt.Sprintf("method %v
not implemented", string(hookType)))
}
```

4、故障转移

启动时候运行一次，拉取pod、容器信息列表，并且写入store缓存中，具体实现代码位于

pkg/runtimeproxy/server/cri/criserver.go的 RuntimeManagerCriServer->failOver

```
func (c *RuntimeManagerCriServer) failOver() error {
    // Try CRI v1 API first. If the backend runtime does not support the v1
API, fall back to using the v1alpha2 API instead.
    podResponse := &runtimeapi.ListPodSandboxResponse{}
    // 拉取pod列表
    var err error
    if c.criServer != nil {
        podResponse, err =
c.criServer.backendRuntimeServiceClient.ListPodSandbox(context.TODO(),
&runtimeapi.ListPodSandboxRequest{})
        if err != nil {
            return err
        }
    } else {
        podResponseAlpha, err :=
c.criAlphaServer.backendRuntimeServiceClient.ListPodSandbox(context.TODO(),
&runtimeapialpha.ListPodSandboxRequest{})
        if err != nil {
            return err
        }
        err = convert(podResponseAlpha, podResponse)
        if err != nil {
            return err
        }
    }

    for _, pod := range podResponse.Items {
```

```
        podResourceExecutor :=
cri_resource_executor.NewPodResourceExecutor()
        podResourceExecutor.ParsePod(pod)
        // 检查POD节点是否存活，并且写入缓存

podResourceExecutor.ResourceCheckPoint(&runtimeapi.RunPodSandboxResponse{
            PodSandboxId: pod.GetId(),
        })
    }

    // 获取容器列表
    var containerResponse *runtimeapi.ListContainersResponse
    if c.criServer != nil {
        containerResponse, err = c.criServer.ListContainers(context.TODO(),
&runtimeapi.ListContainersRequest{})
        if err != nil {
            return err
        }
    } else {
        containerResponseAlpha, err :=
c.criAlphaServer.ListContainers(context.TODO(),
&runtimeapialpha.ListContainersRequest{})
        if err != nil {
            return err
        }
        err = convert(containerResponseAlpha, podResponse)
        if err != nil {
            return err
        }
    }
    for _, container := range containerResponse.Containers {
        containerExecutor :=
cri_resource_executor.NewContainerResourceExecutor()
        if err := containerExecutor.ParseContainer(container); err != nil {
            klog.Errorf("failed to parse container %s, err: %v",
container.Id, err)
            continue
        }
        // 检查Contaier节点是否存活，并且写入缓存

containerExecutor.ResourceCheckPoint(&runtimeapi.CreateContainerResponse{
            ContainerId: container.GetId(),
        })
    }

    return nil
}
```

当有人使用 ParseRequest 的时候，接口位于pkg/runtimeproxy/resexecutor/resource_executor.go，实现代码以Container为例pkg/runtimeproxy/cri/container.go,每次使用InterceptRuntimeRequest的时候会触发ParseRequest，在这里会做检查，如果说container缓存不存在，则会报错，从而阻止InterceptRuntimeRequest继续向下请求。

```
func (c *ContainerResourceExecutor) ParseRequest(req interface{})
(utils.CallHookPluginOperation, error) {
..............

    podCheckPoint := store.GetPodSandboxInfo(podID)
    if podCheckPoint == nil {
        err = fmt.Errorf("fail to get pod(%v) related to container", podID)
        break
    }
}
```

四、动态分析

分析目的，验证 runtimeproxy的功能拦截请求转发给koordlet

1、启动runtimeproxy

```
touch /etc/runtime/hookserver.d/koordlet.json
```

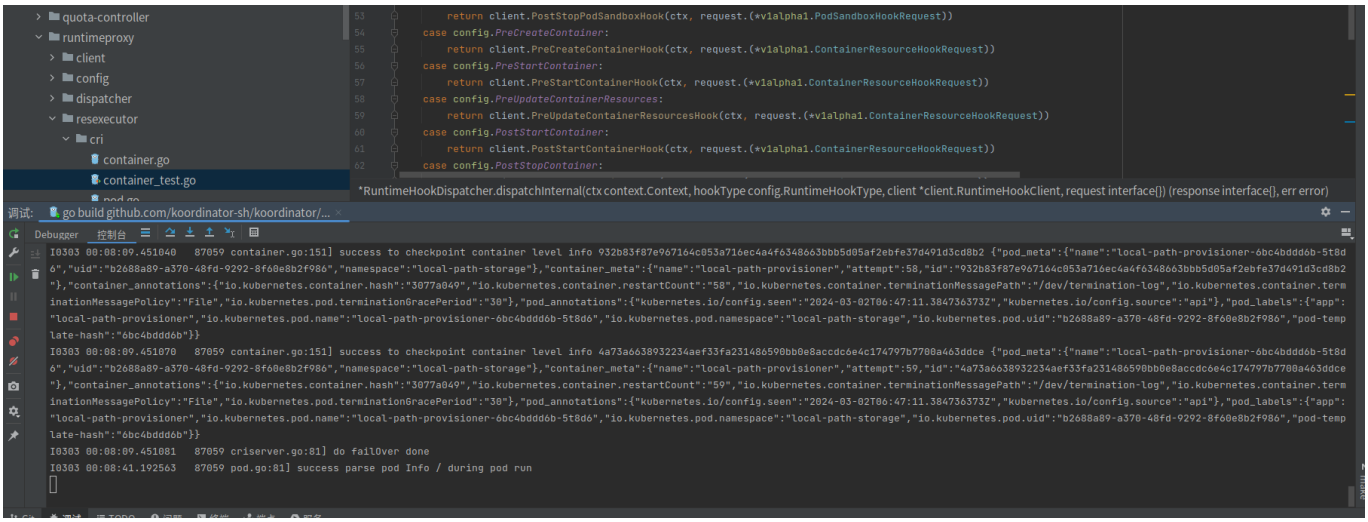
vim /etc/runtime/hookserver.d/koordlet.json 修改文件内容

```
{
    "remote-endpoint": "/var/run/koordlet/koordlet.sock",
    "failure-policy": "Fail",
    "runtime-hooks": [
        "PreRunPodSandbox",
        "PreCreateContainer",
        "PreStartContainer"
    ]
}
```

runtime的启动参数,由于我在本机使用了kind进行测试所以必须加/proc/{pid}/root

```
--remote-runtime-service-endpoint
/proc/4299/root/run/containerd/containerd.sock
```

运行runtimeproxy模块



2、编写cri客户端测试程序

核心代码位于

```
https://github.com/LeiZhang-Hunter/cri-test
```

稍微编写用例改为:

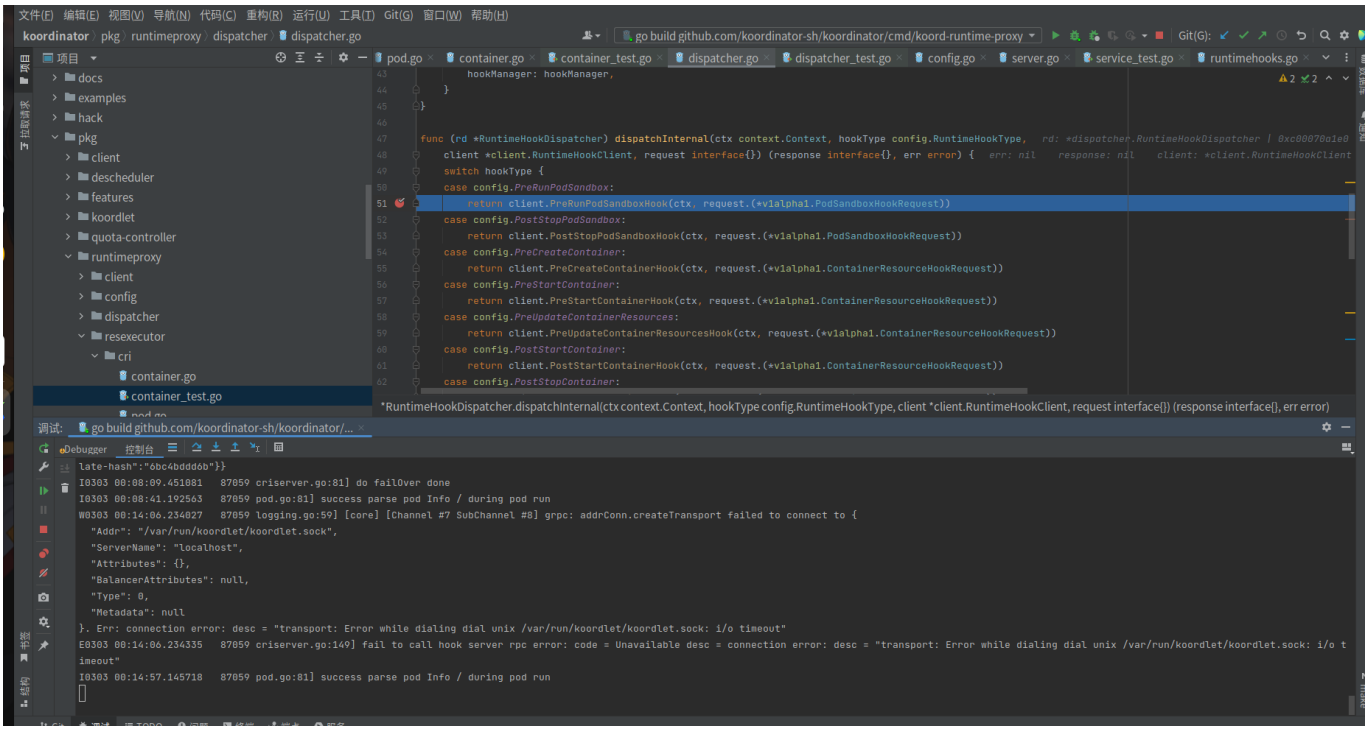
```
func main() {
    InitRuntimeClient()
    all, err := GetRuntimeClient().PreRunPodSandbox()
    if err != nil {
        return
    }
    fmt.Println(all)
    return
}
```

编译二进制，并且运行

```
go build main.go && ./main
```

3、验证是否拦截了RunPodSandbox

如果进行拦截，下一步runtime-proxy 会把请求转发给koordlet，通过打断点验证



发现命中断点

由于没起koordlet，但是我们可以通过报错分析,确实有请求数据转发给了koordlet

```
W0303 00:14:06.234027   87059 logging.go:59] [core] [Channel #7 SubChannel
#8] grpc: addrConn.createTransport failed to connect to {
  "Addr": "/var/run/koordlet/koordlet.sock",
  "ServerName": "localhost",
  "Attributes": {},
  "BalancerAttributes": null,
  "Type": 0,
  "Metadata": null
}. Err: connection error: desc = "transport: Error while dialing dial unix
/var/run/koordlet/koordlet.sock: i/o timeout"
E0303 00:14:06.234335   87059 criserver.go:149] fail to call hook server
rpc error: code = Unavailable desc = connection error: desc = "transport:
Error while dialing dial unix /var/run/koordlet/koordlet.sock: i/o timeout"
```