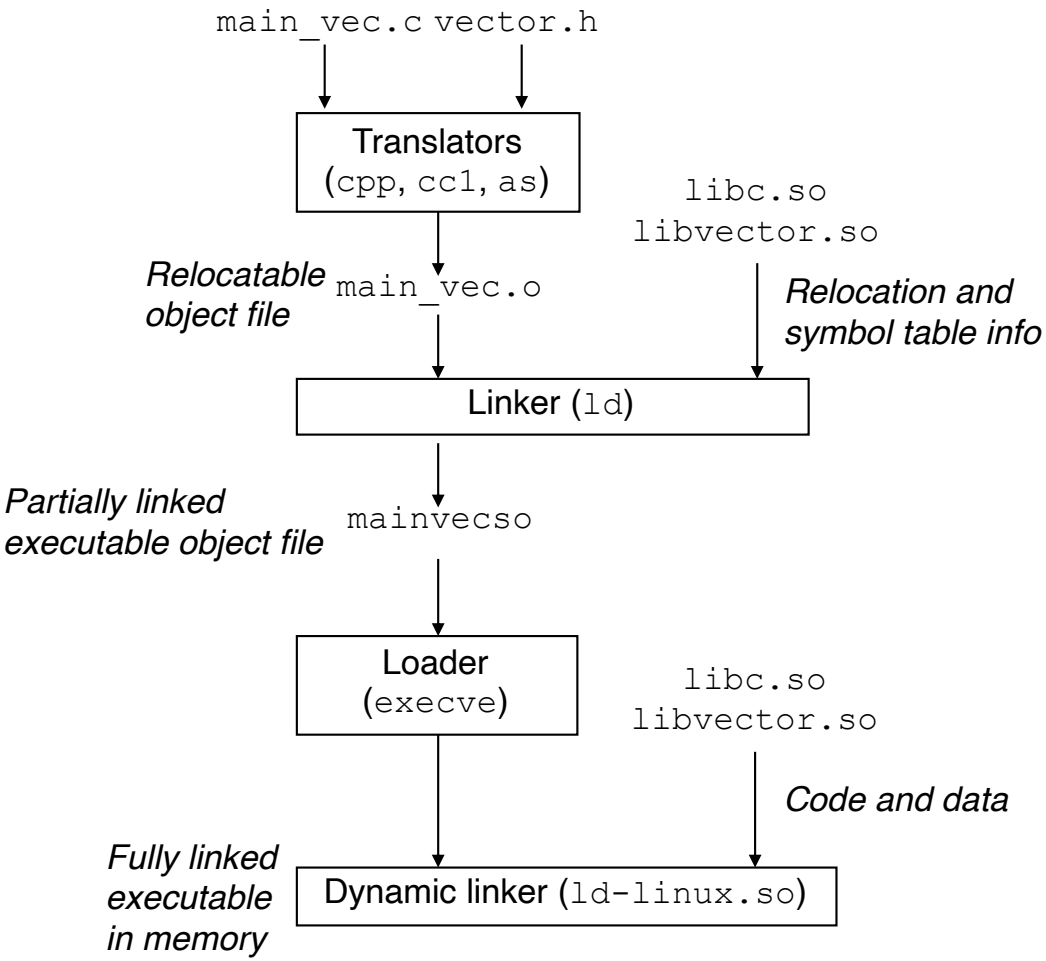
# Dynamic Linking Workflow on Linux



# The Source Files

*vector.h*

```
void addvec(int*, int*, int*, int);
void multvec(int*, int*, int*, int);
int addcount(void);
int multcount(void);
```

*vector_add.c*

```
extern int addcnt;

void addvec(int *x, int *y, int *z, int n) {
  addcnt++;
  for (int i = 0; i < n; i++) z[i] = x[i] + y[i];
}
```

*vector_mult.c*

```
extern int multcnt;

void multvec(int *x, int *y, int *z, int n) {
  multcnt++;
  for (int i = 0; i < n; i++) z[i] = x[i] * y[i];
}
```

*vector_ops_count.c*

```
int addcnt = 0, multcnt = 0;

int addcount(void) {return addcnt;}

int multcount(void) {return multcnt;}
```

*main_vec.c*

```
#include <stdio.h>
#include "vector.h"

int x[2] = {1, 2};
int y[2] = {3, 4};
int z[2];

int main(void) {
  printf("x = [%d %d]\n", x[0], x[1]);
  printf("y = [%d %d]\n", y[0], y[1]);
  addvec(x, y, z, 2);
  printf("z = [%d %d]\n", z[0], z[1]);
  multvec(y, z, x, 2);
  printf("x = [%d %d]\n", x[0], x[1]);
  addvec(z, x, y, 2);
  printf("y = [%d %d]\n", y[0], y[1]);
  return 0;
}
```

*Makefile*

```
VECSRCS := vector_add.c vector_mult.c vector_ops_count.c

libvector.so: ${VECSRCS}
gcc -shared -fpic -o $@ ${VECSRCS}

mainvecso: main_vec.o ./libvector.so
gcc -o $@ main_vec.o ./libvector.so
```

# The Problem

- We have an application binary (`mainvecso`) that links with a dynamically linked library (`libvector.so`), with references that may need run-time resolution.
  - Data references (e.g., to `addcount`, within the library).
  - Code references (e.g., the call to `addvec()` from `mainvecso`).

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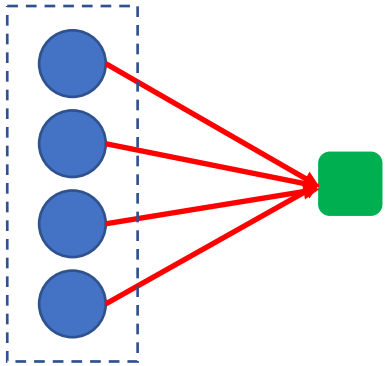
  - Code references (e.g., the call to `addvec()` from `mainvecso`).
- In general, the number of references will be much greater than the number of definitions.
- How do we design an efficient resolution scheme that will allow us to patch lazily and to share the `.text` section of the library among all of its users?
  - ("Lazy resolution") We want to patch only those references that are truly needed during a program run.
  - ("Once-per-definition resolution") We want to minimize the cost of patching multiple references to a single definition.

# The Key Insight

- The problem arises because:
  - we have direct connections from multiple sources (references, in module A) to a single destination (definition, in module B); and
  - we have to patch the source end.



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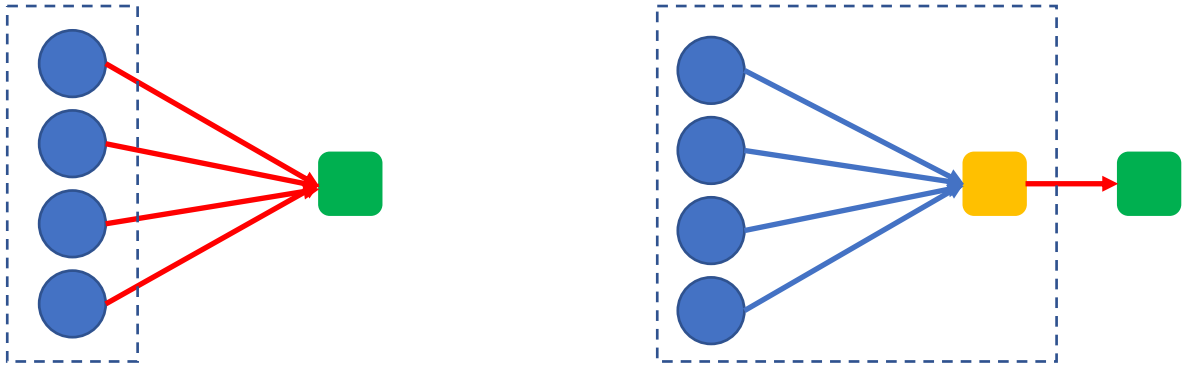

- If we reconfigure the connections to pass through a common “junction box”, then we can patch the single connection from this box to the definition.
  - The Global Offset Table (GOT) is just this junction box.
  - The Procedure Linkage Table (PLT) is a mechanism to make sure that the blue edges remain PIC.

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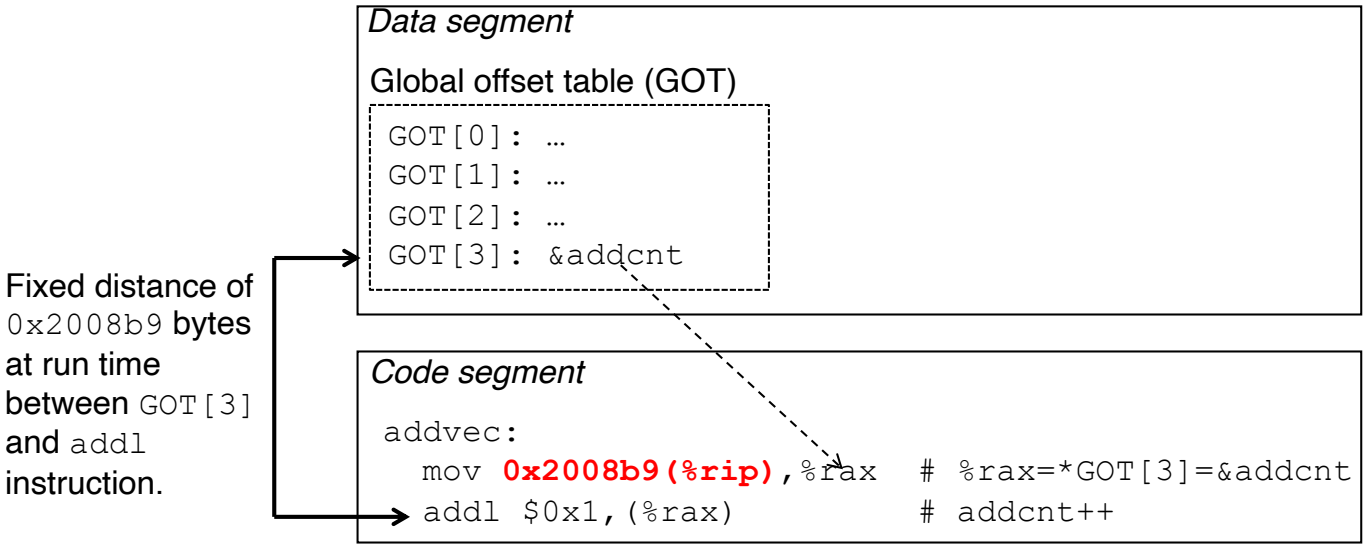
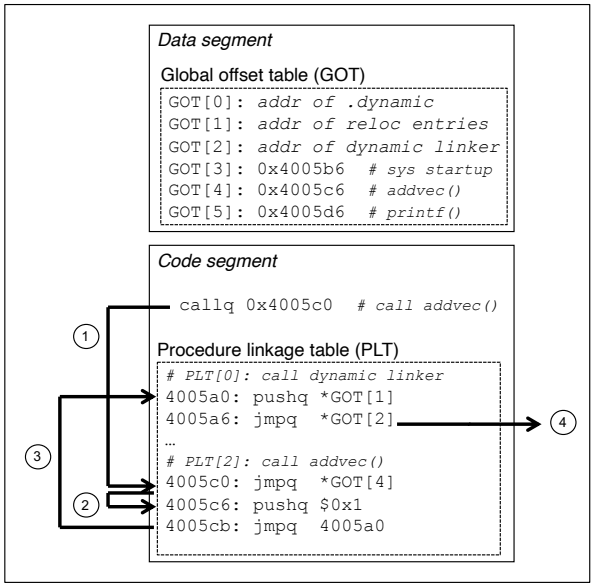
  - Consists entirely of stubs of a well-defined format, dedicated to directing calls from the `.text` section to the appropriate library function.
- There will also be `.rel.dyn` and `.rel.plt` sections in the ELF file to enable the dynamic linker to do its job of initializing GOT entries correctly.

# Patching Data References




- The dynamic linker relocates each GOT entry to the absolute address of each global variable.
- This uses the special RIP-relative addressing mode, which is available on x86 only in 64-bit mode.
  - A bootstrapping trick is needed in 32-bit mode.

# Patching Code References

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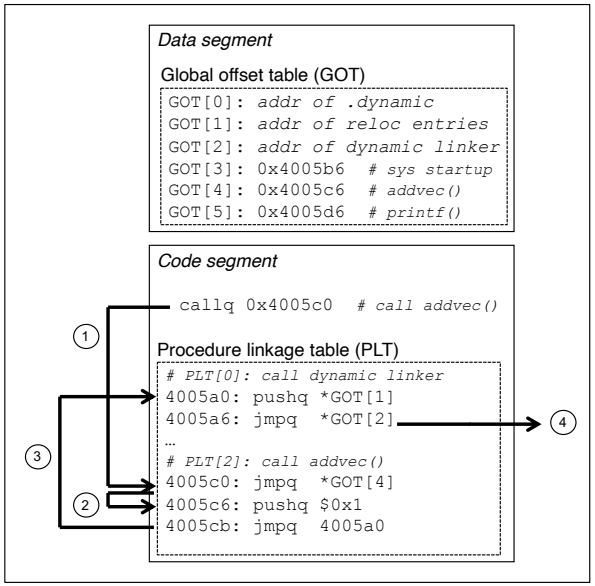


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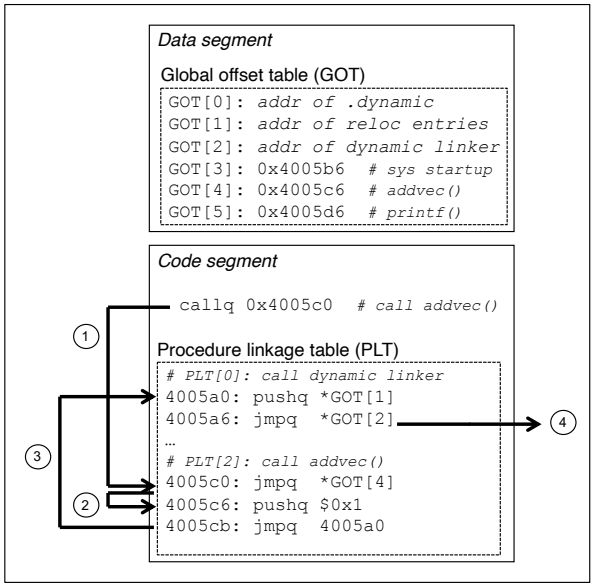


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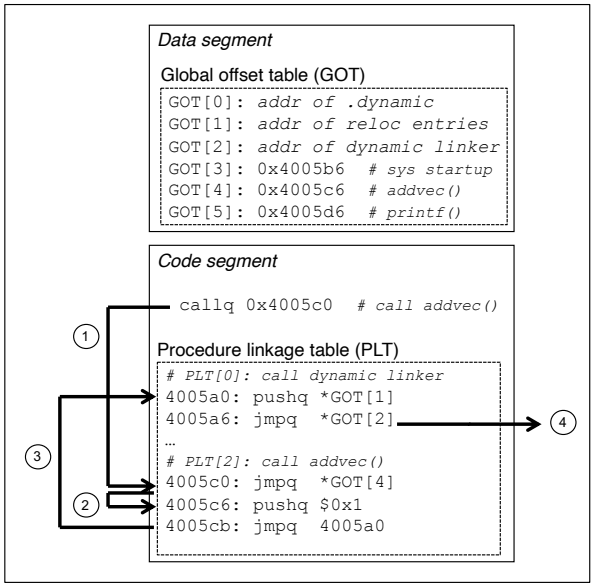


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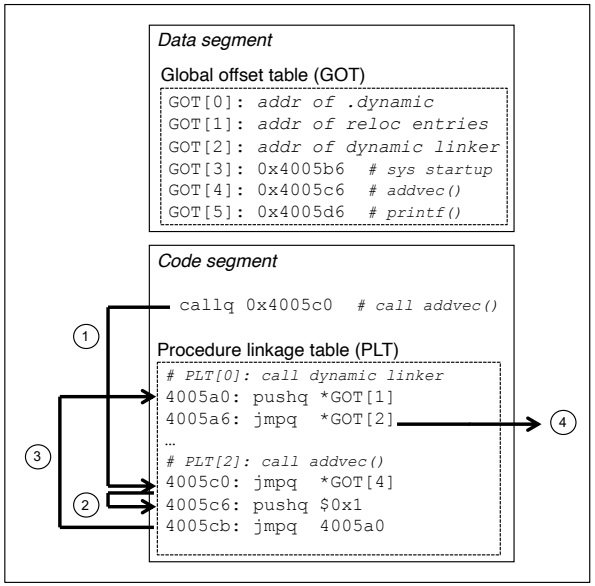


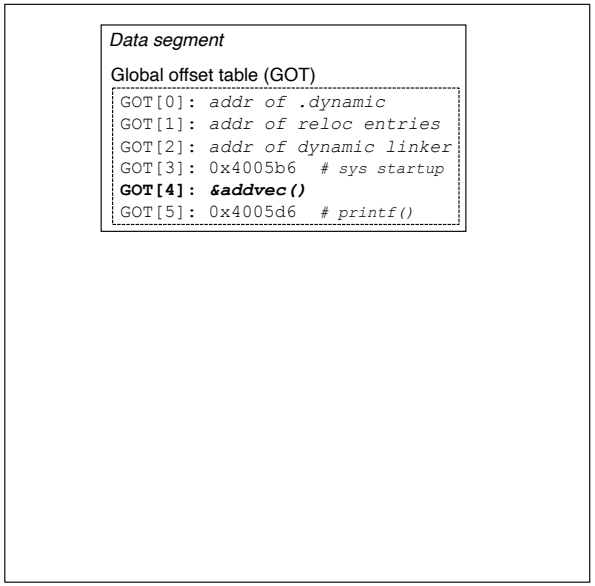


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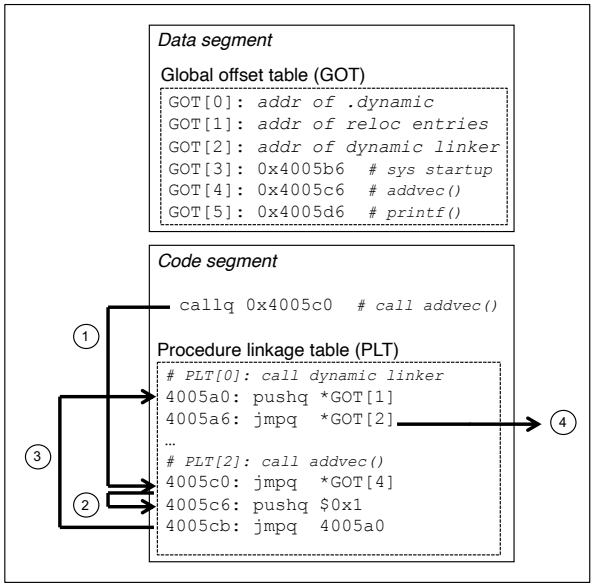



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5. The dynamic linker patches the reference by **updating** `GOT[4]` to the RT address of `addvec()`, and then jumps to that routine.
6. On subsequent calls to `addvec()`, the indirect jump through `GOT[4]` in step #2 bypasses the following steps and goes directly to the routine.