Object Code Emission & llvm-mc

LLVM Developers Meeting, 2009
Cupertino, CA

Bruno Cardoso Lopes
bruno.cardoso@gmail.com

Introduction

- Motivation
- Background
- Actual Code Emission
- Object Code Emission
- llvm-mc

Motivation

- Known path

$$\begin{tikzcd}\boxed{\texttt{Compiler}} \arrow[r, "\texttt{.s}"] & \boxed{\texttt{Assembler}} \arrow[r, "\texttt{.o}"] & \boxed{\texttt{Linker}}\end{tikzcd}$$

- Object code path

$$\begin{tikzcd}\boxed{\texttt{Compiler}} \arrow[r, "\texttt{.o}"] & \boxed{\texttt{Linker}}\end{tikzcd}$$

Motivation

- Why direct object code emission?
  - Bypass the external assembler.
  - Speed-up compile time.

Background

- Current code emission:
  - Asm printers
  - JIT engine

Asm Printer

- AsmPrinter
    - Instructions are described on .td files.
    - Auto-generated method is used to print instructions.

Asm Printer

```
void X86AsmPrinter::printMCInst(const MCInst *MI) {
  if (MAI->getAssemblerDialect() == 0)
    X86ATTInstPrinter(0, *MAI).printInstruction(MI);
  else
    X86IntelInstPrinter(0, *MAI).printInstruction(MI);
}
```

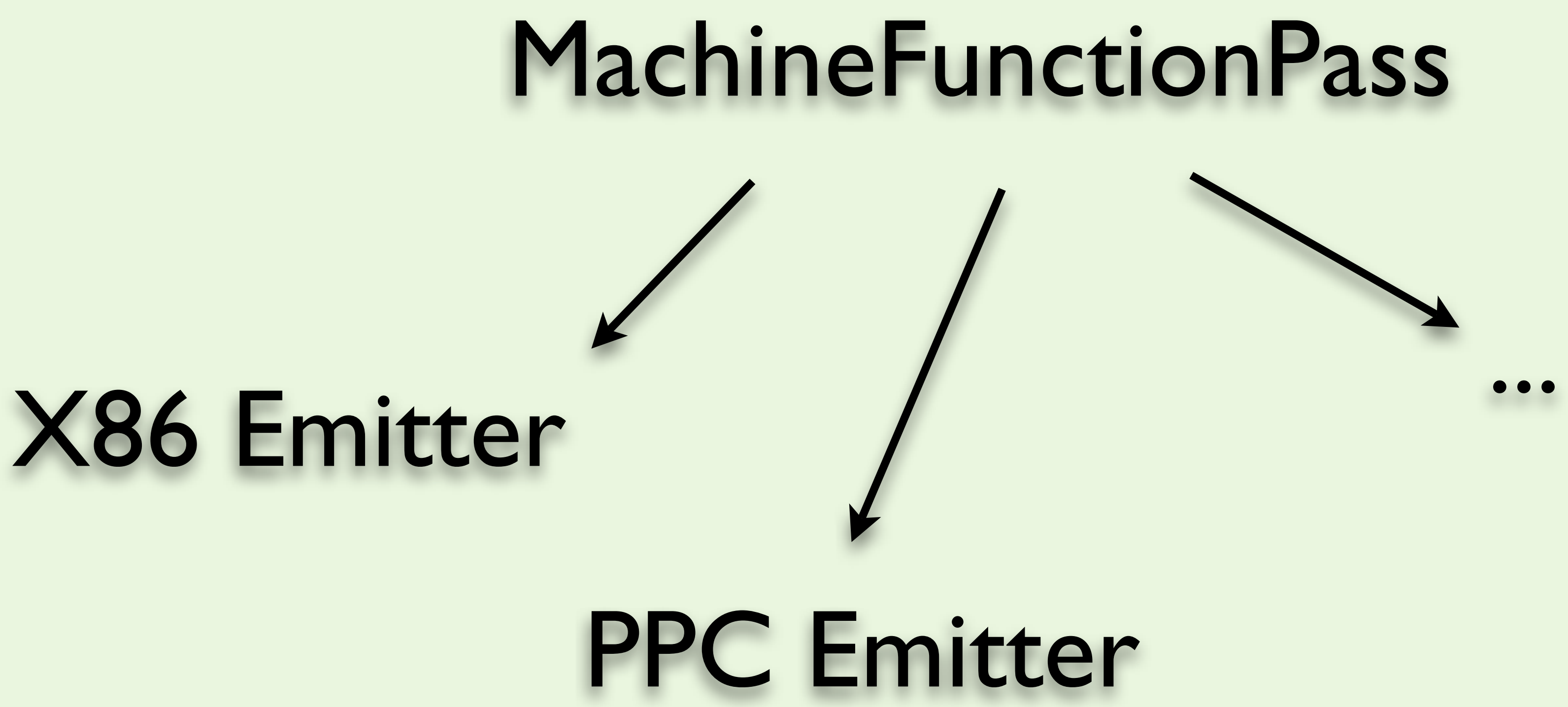
Auto-generated method

JIT

- JIT emits binary code.
- Blobs are emitted to memory by a target specific code emitter class.

JIT

- The code is emitted per-function



JIT

- Only PPC has a auto-generated code emitter.

```
...
class Emitter : public MachineFunctionPass {
  ...
  bool runOnMachineFunction(MachineFunction &MF);

  void emitInstruction(const MachineInstr &MI,
                       const TargetInstrDesc *Desc);
  ...
```

MachineCodeEmitter

- The actual binary code emission is done by calls to the **MachineCodeEmitter.**

```
void ...emitInstruction(const MachineInstr &MI, ...) {

  // Emit the lock opcode prefix as needed.
  if (Desc->TSFlags & X86II::LOCK)
    MCE.emitByte(0xF0);
  ...
```

MachineCodeEmitter

JITCodeEmitter

- JIT code emission is implemented in the JITCodeEmitter.
- A specialization from MCE.
- Implement methods to actually write to memory:

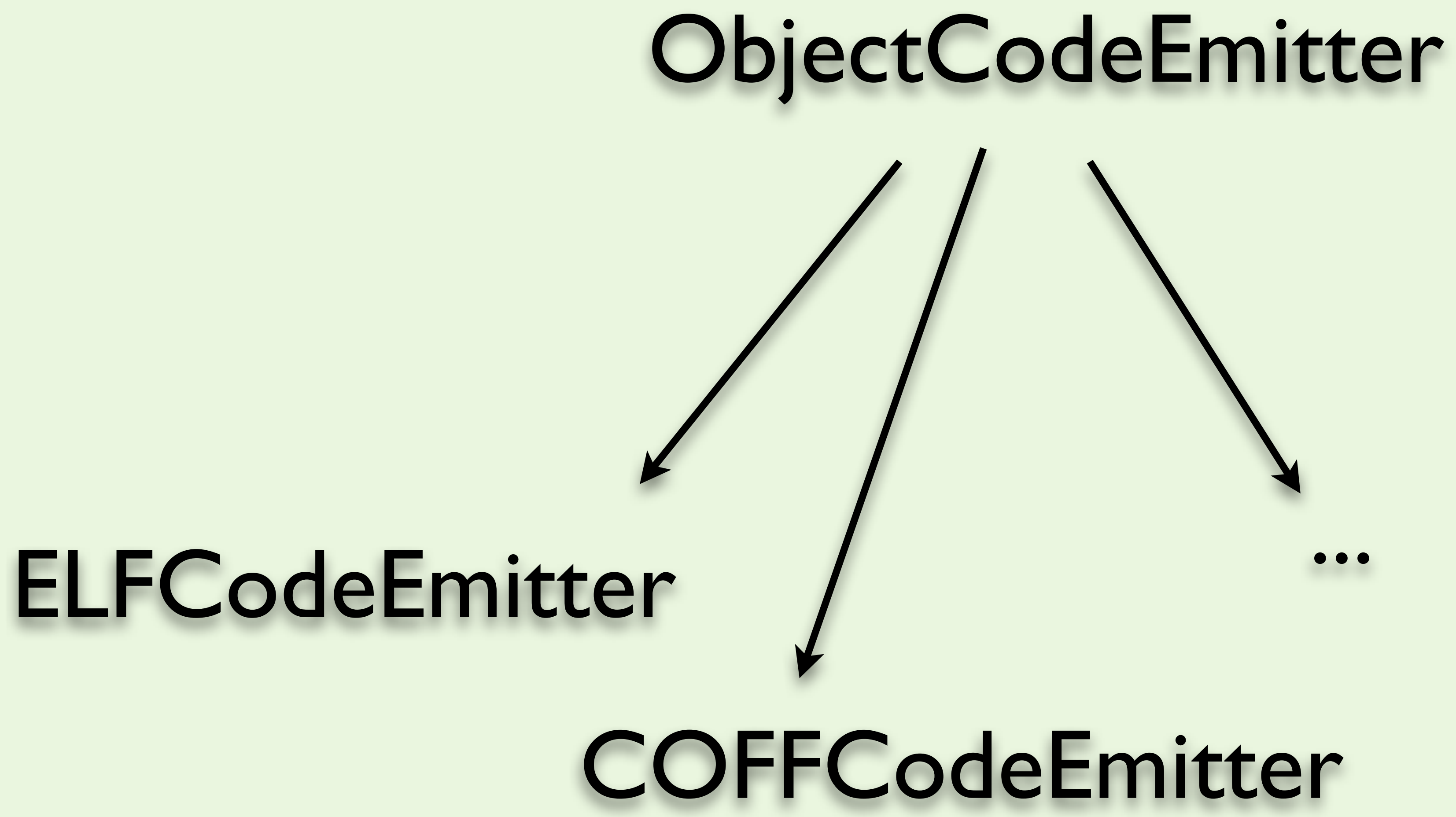
```
emitByte(..)
emitULEB128Bytes(..)
emitDWordLE(...)
emitAlignment(...)
```

Object Code

- Object Code support is implemented using this scenario.
- Specialize the MCE as JIT does.
- MCE is an instance of ObjectCodeEmitter.

Object Code

- The specific formats (e.g. ELF) are specializations of ObjectCodeEmitter.



Object Code

- Blobs of code and data are written to **BinaryObjects.**
- High level abstraction of "Sections" or "Segments".

```
class ELFSection : public BinaryObject {
  public:
  ...
```

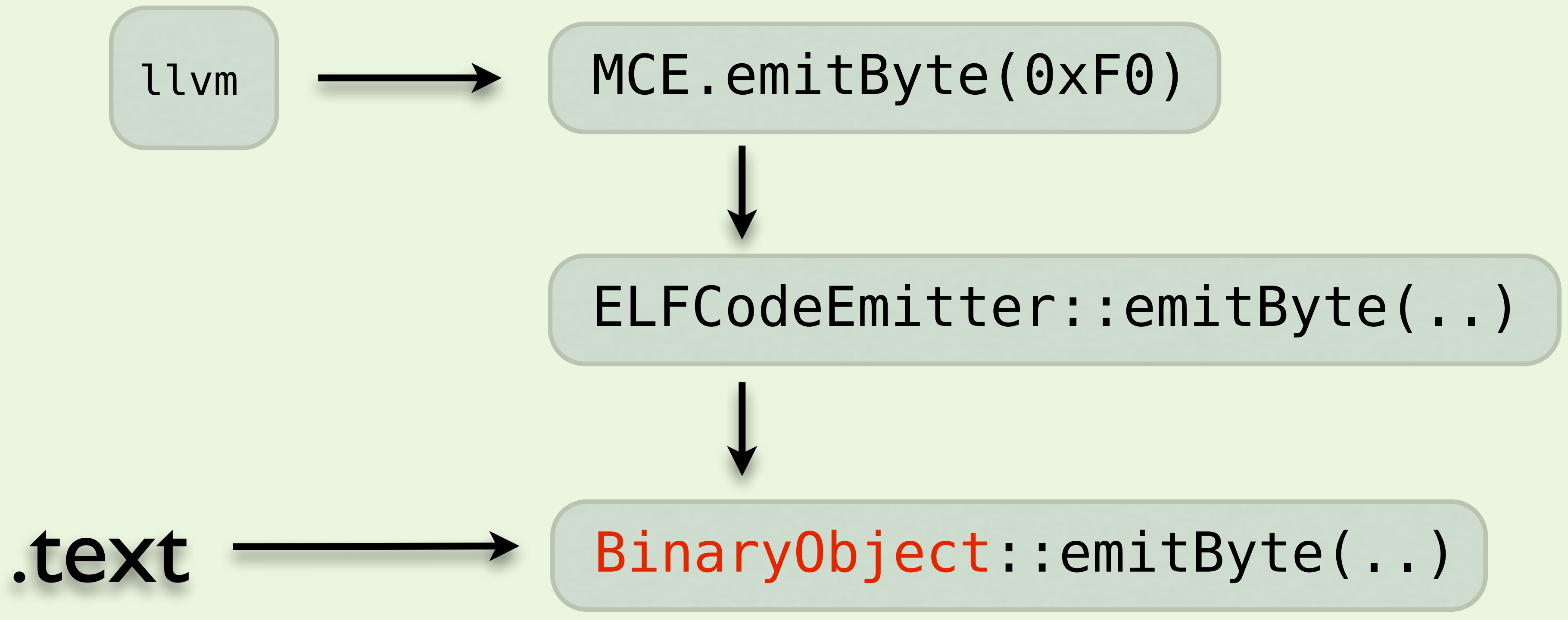
ELFCodeEmitter

- Handling of ConstantPools and Jumptables.
  - On each binary format a different section.
- Generic target relocations to ELF specific ones.

$$\begin{tikzcd} \text{llvm::reloc\_absolute\_word} \arrow[dr] & \\ & \text{R\_X86\_64\_32} \end{tikzcd}$$

ELFCodeEmitter

- The ELFCodeEmitter emits code to BinaryObjects.



ELFWriter

- Emits the symbol table, string table, header and relocations into binary objects.
- Dump binary objects to a final file.

Limitations

- Inline assembly not handled by emitters.
- That demands an assembly parser.
- Solution: **llvm-mc**.

llvm-mc

- Machine code driver.
- Current playground for an assembly parser, assembler and disassembler.

llvm-mc

- **Goals:**
  - Extract all info from .td files.
  - Auto-generate a assembler, disassembler and code generator.
  - Integrate the assembler into the compiler.

llvm-mc

- **Goals:**
  - At least ~20% speedup at "-O0 -g".
  - Share binary writers code base as much as possible among different formats.

llvm-mc

- **In progress:**
  - Parse a assembly file and dump the Lex tokens.

```
.data
.ascii "hello"
```

-as-lex →

```
identifier: .data
EndOfStatement
identifier: .ascii
string: "hello"
EndOfStatement
```

llvm-mc

- **In progress:**
  - Parse and assemble a .s file, emitting asm again or object code.

```
$ llvm-mc -assemble -output-asm-variant=0
  -show-encoding x86.s

  .section  __TEXT,__text,regular,pure_instructions
  subb  %al, %al
                          # encoding: [0x28,0xc0]
  addl  $24, %eax
                          # encoding: [0x83,0xc0,0x18]
```

llvm-mc

- **In progress:**
  - A complete assembler: includes relaxation phases, which allows late optimizations
  - Example: Jump instruction encoding on x86.

llvm-mc

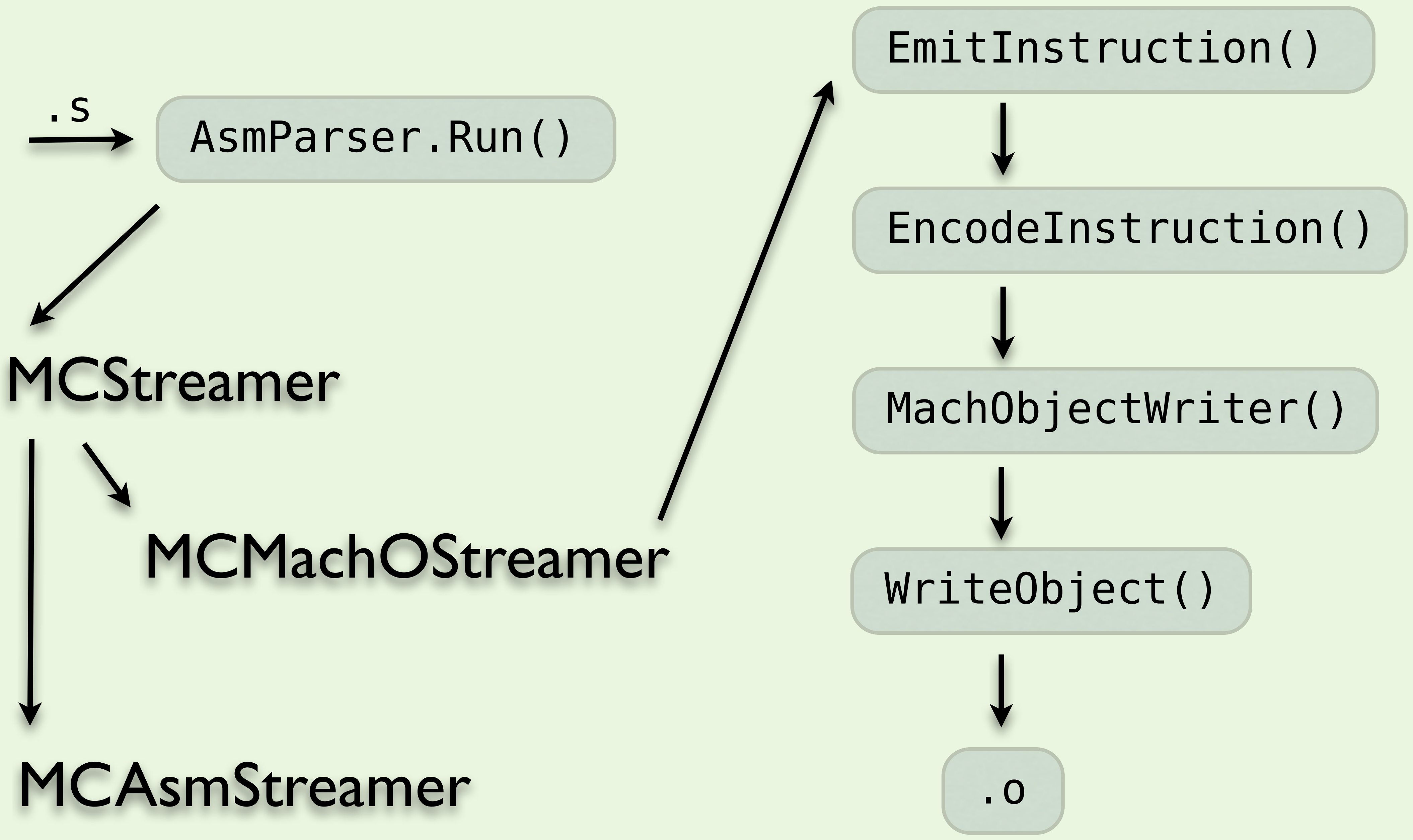
- **In progress:**
  - Interactive disassembler: makes easier to write regression tests for instruction encoding

```
$ llvm-mc -disassemble

74 22 ←—— user input

1 instruction:
74 22 je 34
```

llvm-mc

- **Architecture**
  - The asm parser emits code through a generic streamer, **MCStreamer**.
  - The streamer is specialized to emit asm or object code.

llvm-mc


.s
AsmParser.Run()
MCStreamer
MCMachOStreamer
MCAsmStreamer
EmitInstruction()
EncodeInstruction()
MachObjectWriter()
WriteObject()
.o

llvm-mc

- **Current limitations**
  - Quite new and experimental.
  - Demands lots of clean up and refactoring.
  - Hardcoded for MachO.

llvm-mc

- **Current limitations**
  - ELF emission is not integrated into the llvm-mc architecture.
  - ELF assembly parsing bits not implemented.
  - The Assembly printer is not entirely converted to use **MCAsmStreamer**.

llvm-mc

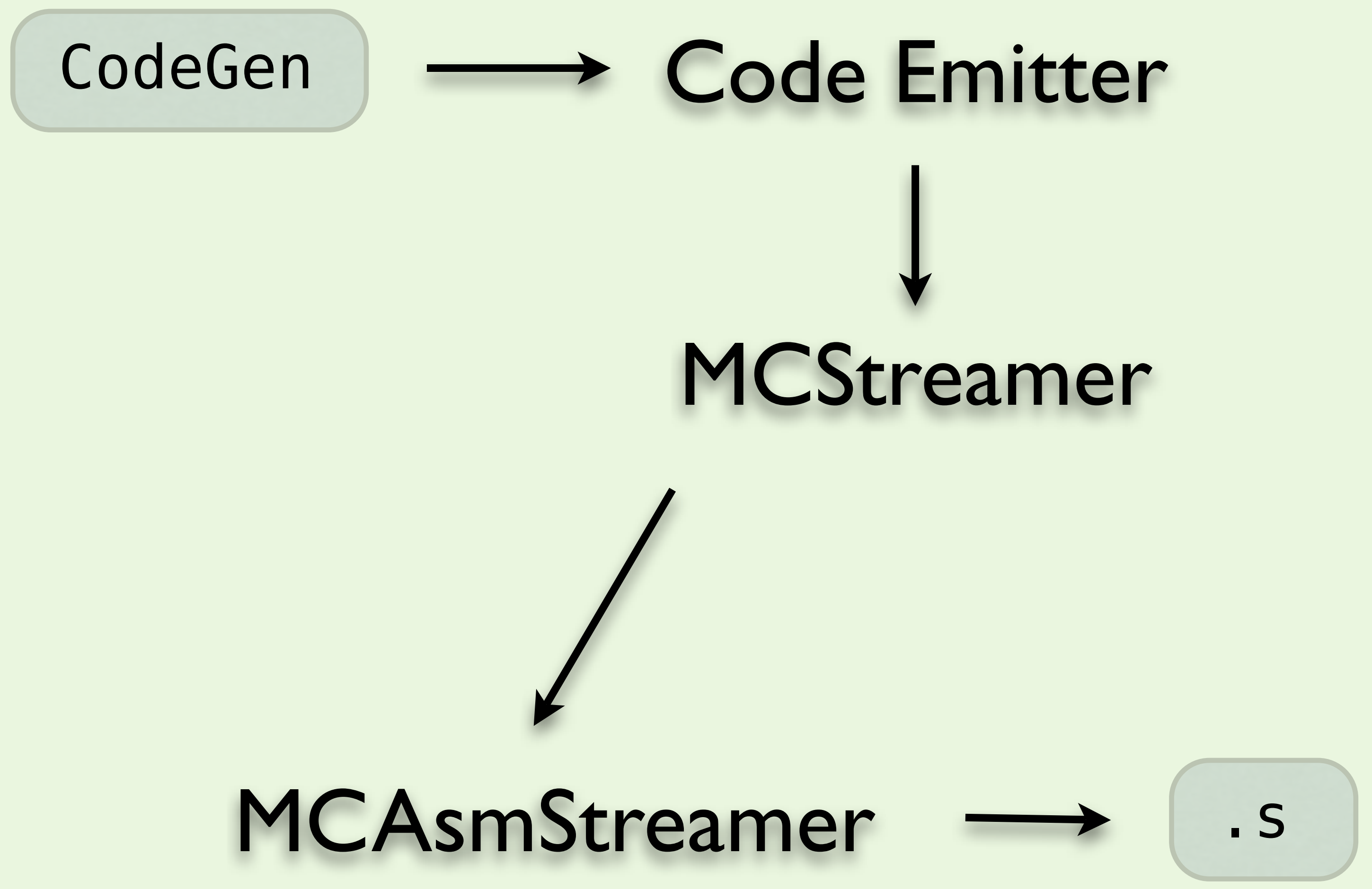
- **MCStreamer future:**
  - Support other binary formats.
  - New specializations for: JIT, dwarf EH and debug info.

llvm-mc

- **MCStreamer future:**
  - JIT and asm printers will eventually be merged into only one “emitter”.
  - “-S” could generate “verbose assembly” by default (loop depth, encoding info, ...)

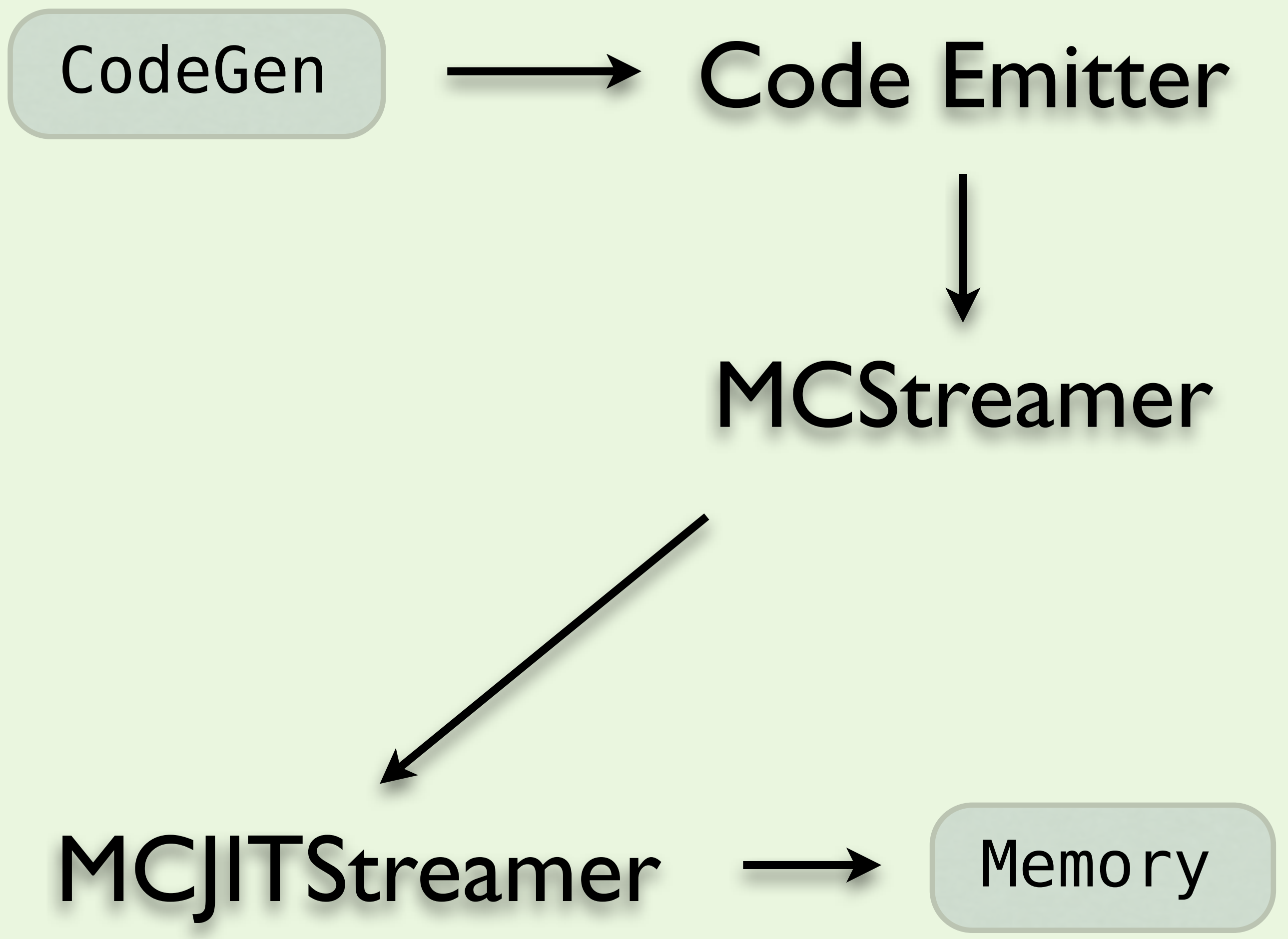
Future Design

- **Printing .s**



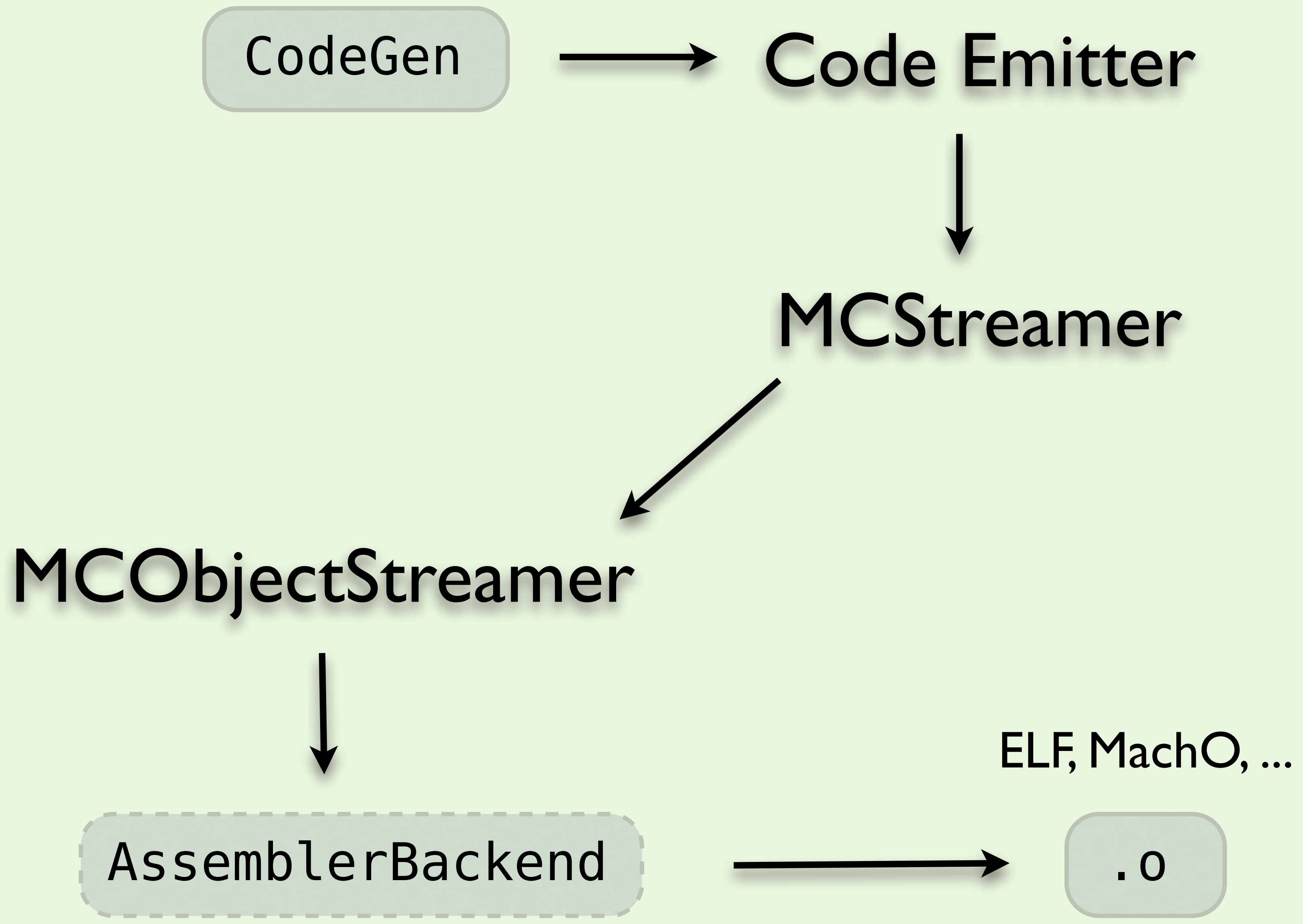
Future Design

- **JIT**



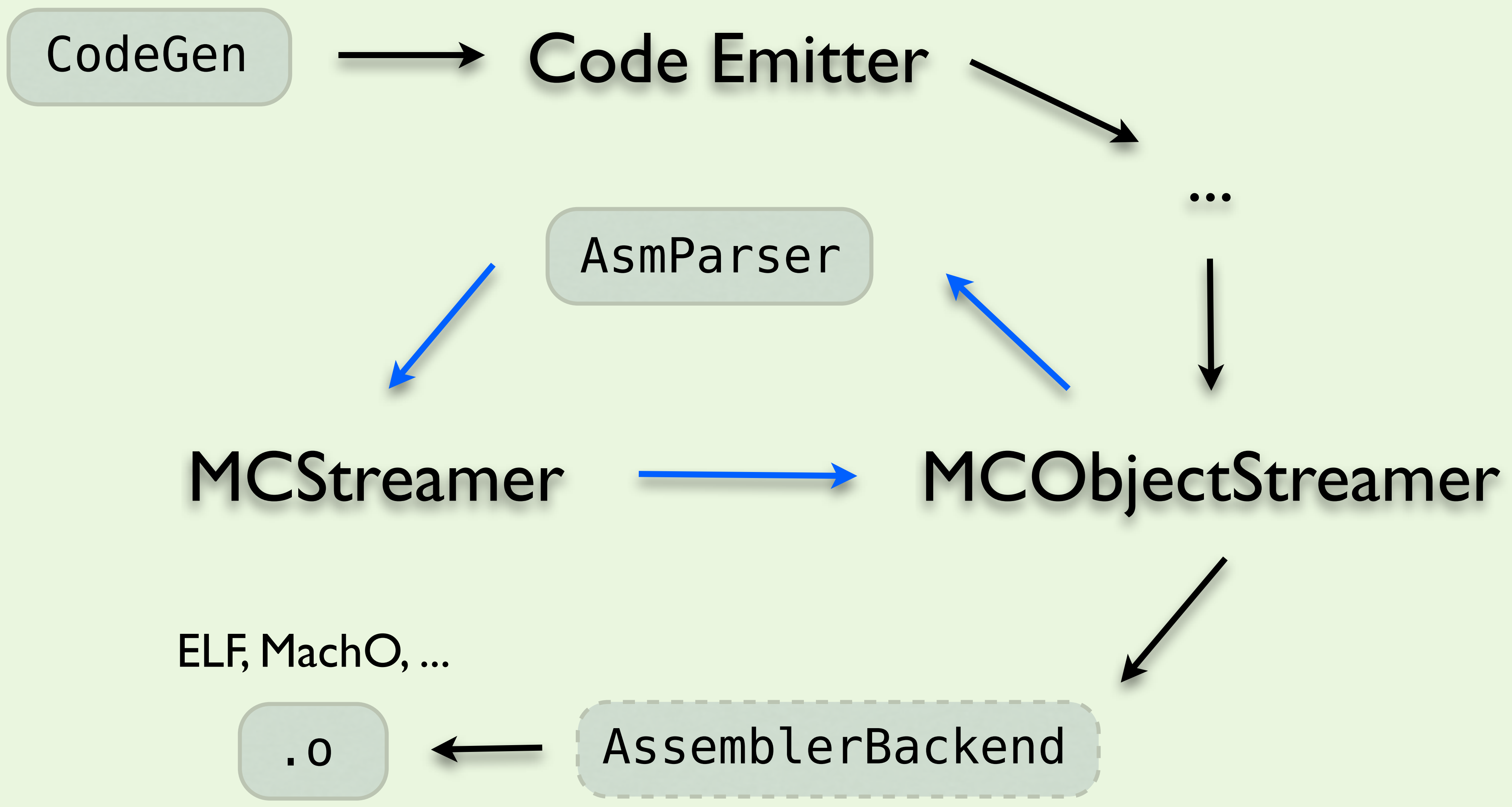
Future Design

- **.o writing**

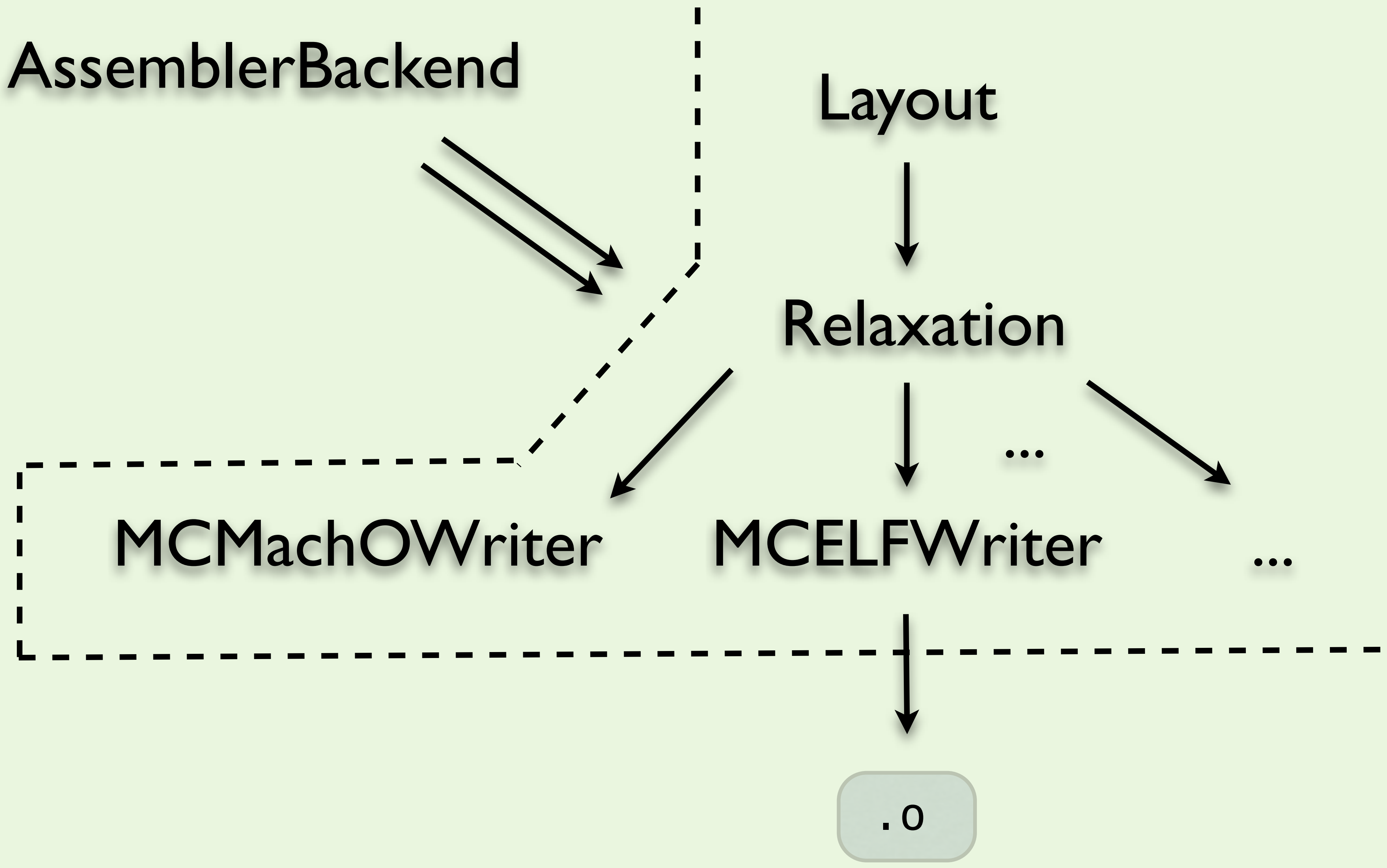


Future Design

- **Inline asm for .o file writing**



Future Design



Object Code Emission & llvm-mc

Questions?

Bruno Cardoso Lopes
bruno.cardoso@gmail.com